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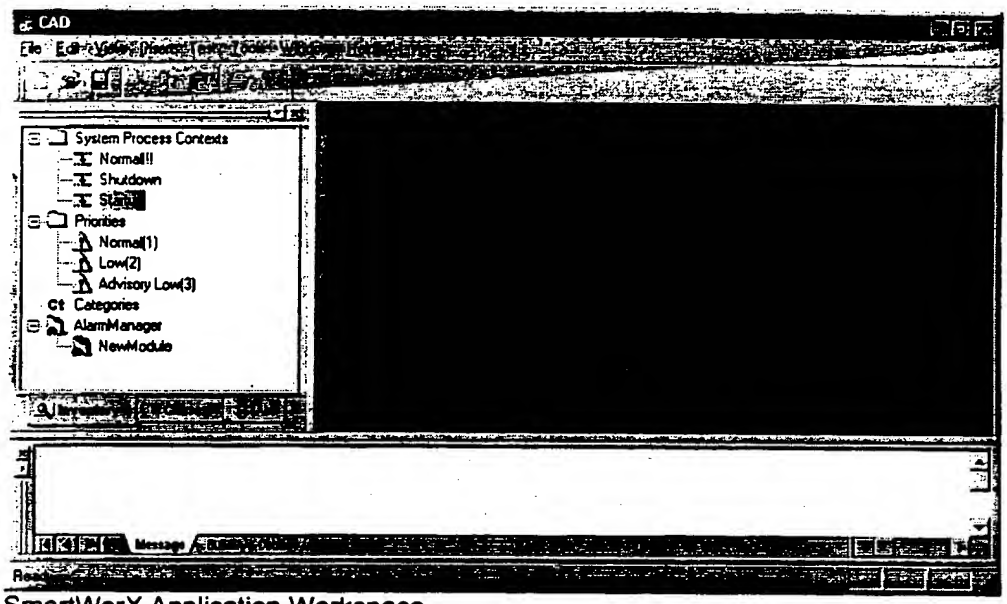
(54) **SYSTEME EXPERT ET METHODOLOGIE CONNEXE**
(54) **EXPERT SYSTEM AND METHODOLOGY**



SmartWorX Application Workspace

(57) La présente invention a trait à un système expert capable d'assurer le fonctionnement optimal d'un processus, ainsi que le maintien d'un tel fonctionnement; le système peut également utiliser des méthodes de saisie et d'application de connaissances d'experts et les intégrer à un système à base de règles qui peut être mis en oeuvre par des opérateurs qui ne sont pas des spécialistes en ingénierie de la connaissance. Idéalement, le système peut être mis en oeuvre par un ordinateur et interfacer directement avec un système de commande de processus.

(57) The present invention is an expert system for optimizing and maintaining a process, employing methods of capturing and implementing knowledge from experts and consolidating same into a rule-based system capable of application by operators without knowledge engineering expertise. Ideally, the system may be computer implemented, and may interface directly with a process control system.

ABSTRACT OF THE DISCLOSURE

The present invention is an expert system for optimizing and maintaining a process, employing methods of capturing and implementing knowledge from experts and consolidating same into a rule-based system capable of application by operators without knowledge engineering expertise. Ideally, the system may be computer implemented, and may interface directly with a process control system.

Description of Field of Invention

The present invention relates generally to expert systems, and more particularly, to methods of capturing and implementing knowledge from an expert in a particular field (also referred to as a domain expert) into a rule-based expert system. An expert system uses a knowledge base and human knowledge and expertise to make decisions. Such a system can be queried by a human operator or can be embedded into or consulted in real-time by an external system, including but not limited to a process control system.

Background

In recent years, expert systems have been implemented to control and optimize real-time process control equipment. While such expert systems possess important advantages, there are currently significant limitations connected with their development and implementation, and maintenance.

The development of such expert systems has required involvement of persons with specialized training and experience in the field of expert system developed, known as knowledge engineers, in order to capture expert knowledge from a domain expert and translate such information into a series of rules that can be processed by an expert system. Many users of expert systems have enrolled in training programs to better understand the process of developing expert systems. However, even following completion of such training programs, many users still have considerable difficulty developing an expert system without the assistance of experienced knowledge engineers.

The general approach utilized in the development of expert systems is to directly formulate rules and procedures to be executed by the expert system. This is typically done without use of a structured approach or methodology. Even when a knowledge engineer is utilized, the lack of a workable methodology often means that operators and end users of expert systems, including plant operators, must spend considerable time (in some cases, several months) debugging and tuning the initial application. As a result, the success rate of an initial expert system application is often uncertain and the resulting expert system application if often difficult to maintain. The problem is expected to worsen as larger, more complex expert systems are developed to handle more sophisticated tasks.

Thus, it would be an advantage in the art to have an expert system which can efficiently and accurately capture knowledge from a domain expert and structure such knowledge into a form that can be implemented into a rule-based expert system without the use of a knowledge engineer.

Summary of the Invention

Ideally, it is desirable to create an expert system in an efficient manner, without the assistance of a highly skilled knowledge engineer and using a process that is likely to provide a high level of success. The present invention facilitates this much needed capability by

structuring the knowledge acquisition process through interviewing and consolidation, and facilitates the knowledge-based development process, such that these series of steps can be completed efficiently and with predictability by users without specialized training in the development of expert systems.

Some of the attributes of the present invention include:

- The specific questions asked during knowledge gathering and the order or sequence in which they are asked.
- The way that the interview notes or knowledge gathered are translated into classes, objects, rules and procedures, including in this process: error checking, validation, structuring.
- The way that the knowledge base runs when deployed due to the applied structure and specific functions.
- The specific support for making changes/enhancements to the completed system over the life of the application.

The preferred embodiment for the present invention is a Microsoft-based component software application called the "Expert Optimizer". The preferred embodiment models the methodology and applies it to the different processes in the creation of an expert system knowledge base. The Expert Optimizer software application will operate within any OLE container that supports a real-time database.

Methodology

Expert Optimizer advances the state-of-the-art in process optimization by incorporating time proven methodology for successful development of knowledge bases that provide the following benefits:

- Increase production.
- Reduce cost of production.
- Reduce operating variances.
- Increased operator productivity through alarm filtering and operating aid.
- Documentation of process "know how".
- Standardization of operating procedures.

Expert Optimizer offers an easy to use configuration tool that requires minimal training. Knowledgeable plant personnel are able to customize a powerful expert control strategy that matches their operating philosophy.

Expert Optimizer assumes the position of the Knowledge Engineer, in that it has the ability to:

- Conduct an interview of a domain expert.
- Reorganize interview notes.
- Edit notes to form knowledge base rules.

- Structure rules.
- Optimize acquired knowledge.
- Debug a knowledge base.
- Debug an on-line and off-line knowledge base.
- Optimize existing knowledge base.

Some of the unique features of the Expert Optimizer include:

- Automatic generation of documentation.
- A context-sensitive help system that can provide explanations and just-in-time training at any point.
- Ease of customization through features which include:
    - Help in defining the optimum application configuration.
    - Automatic recognition and registration of tags from other systems, e.g., PLC, DCS, and data feeds.
    - Object-oriented data manipulation (adding/changing/deleting attributes and values).
    - The ability to rapidly develop and test applications.
    - Automatic application documentation generation.
    - Controls to customize the behaviour of the system in response to certain inputs, data states, and conditions.
    - Access to data that is distributed across a network.
    - Expert reasoning.
    - Flexible information filters to reduce the amount of information received by any object or tool.
- Ability to modify developed knowledge base on-line without shutting down the system.
- Project management features, including:
    - Object/data usage maps and dictionaries.
    - Version management of application files to ensure latest versions are used to build the application.
- Flexible logging of messages.
- Facilities for self-diagnosing, error reporting, and application debugging.
- Support for various configurations (hardware and communications).
- Saleable from small standalone to distributed complex systems.
- Tutorial which can operate in automatic (demo) mode or interactively and which incorporates multimedia support to provide voice and video.
- Use of an expert system or on-line advisor that guides a user during the various phases of the methodology by monitoring the user's actions and providing unsolicited comments or warnings where appropriate.

The present invention consists of a number of inter-related phases.

Objective Identification

The first step of the methodology involves defining the objectives to be achieved by the expert system. A required objective is process stabilization. The user is also queried for any additional optimization objectives. Examples of such additional optimization objectives include increased production (including throughput), reduced downtime, reduced costs, reduced operating variances, standardization of operating procedures and increased operator productivity through alarm filtering and operating assistance.

Information Gathering Phase

The second step of the methodology is the information gathering phase. It consists of structured interviews of domain experts, to collect and organize information (specific knowledge and experience) known to one or more domain experts, pertaining to the process stabilization and other objectives previously identified. The first goal of the interview is to document the problems, potential causes of each problem and appropriate solutions for each cause in order to achieve the stabilization objective. The second goal of the interview is to document the opportunities, potential constraints for each opportunity and appropriate actions for optimization in order to achieve the optimization objectives.

For each problem that is listed by a domain expert, the expert is asked to document one or more indicators that would confirm the existence of the problem. For each problem that is listed by an expert, the expert is also asked to identify one or more potential causes. For each cause, the expert is asked to list one or more methods of verifying that each such cause exists. For each cause the expert is also asked to list one or more corrective actions that can be taken. As each list of problems, cause and actions are completed, the expert is asked to prioritize the elements of each list.

For each opportunity that is listed by an expert, the expert is asked to describe how he identifies that the opportunity exists. For each opportunity that is listed by an expert, the expert is also asked to identify one or more potential constraints. For each constraint, the expert is asked to list one or more methods of verifying that each such constraint exists. For each constraint the expert is also asked to list one or more optimization actions that can be taken. As each list of opportunities, constraints and actions are completed, the expert is asked to prioritize the elements of each list.

The interview of each domain expert is conducted in a manner that maximizes the opportunity to collect the relevant knowledge known by that expert. As each new expert is interviewed, the same interviewing process is conducted rather than initially asking that expert to build on information provided by prior experts. This is done to elicit broader feedback than would be possible if each expert was given initial access to information provided by previous experts. As each item of information is entered, it can be cross referenced to an equivalent description provided by a previous expert.

The foregoing objectives are accomplished through the following specific interview questions:

- How do you expect the Expert System can improve the process
- What problem can occur that upset the process
- How do you verify that <problem> is happening
- List all the causes for <problem>
- How do you verify that <problem> is caused by <cause>
- List all the actions that can be taken when <problem> occurs
- What <cause> is the reason for <problem>, what corrective actions do you take to remedy the problem
- What process conditions need to present before <corrective action> can be performed
- Can <corrective action> be repeated, how many times, at what interval
- What is the alternative to <corrective action>
- When do you have an opportunity to <objective>
- How do you verify this <opportunity> exists
- What are possible constraints to perform actions when <opportunity> presents itself
- How do you verify these <constraints>
- What are the possible actions to take when <opportunity> to <objective>
- What process conditions need to present before <action> can be performed
- Can <action> be repeated, how many times, at what interval
- What is the alternative to <action>

In respect of each corrective or optimization action, the following details are requested:

- a description of the actual action to be performed
- any process conditions that must be met before the action can be performed
- the number of times the action can be repeated and a period of time that the system should wait before re-evaluating whether the action should be repeated
- an alternative action to be performed in the event that problem is not solved, or the optimization opportunity still exists, after repeating the initial action for the specified maximum number of times

The questions asked will differ depending on whether one or multiple domain experts are to be interviewed.

Consolidation Phase

The information gathering phase in the methodology is followed by a consolidation phase which involves the association of related items in a group (which include problems, problem identification methods, causes, cause verification methods, corrective actions, opportunities, opportunity identification methods, constraints, constraint verification methods, optimization actions) into a new consolidated item in the same group and is then followed with a prioritization of the consolidated items in each such group. In this way, the information obtained from the multiple domain experts is consolidated together.

On a group by group basis, each item within a group is plotted on the Y axis of a grid and an indication of each expert that raised that item is plotted on the X axis, in order to facilitate the association process. When the methodology is embodied into a software program, this phase makes use of a graphical user interface to assist with the association process. Related items, which are identified using the grid, are associated together into one new item. For each associated item, information captured from each expert can be copied and pasted into the consolidated new item. Even if information is not copied from a particular associated item into the consolidated item, the item remains associated with the consolidated item (for future reference but not for use by the expert system). Original notes are not deleted but rather are linked to new notes which resolve conflicts or summarize multiple original notes.

The next step involves a prioritization, on a group by group basis, of each item within the group with the initial prioritization is performed based on an averaging of the prioritizations set by each expert, although this is also subject to adjustment. An exception is made for problems and opportunities, where both types of such items are sorted together into a single common group. However, in this common list of problems and opportunities, all problems are initially listed before any opportunities, although this is subject to adjustment.

The next step involves reviewing each action to identifying other actions that are to be disabled, and the applicable wait period, while the current action is performed.

Process Object Definition Phase

The consolidation phase results in text notes for each consolidated item, with the exception of actions which may also be assigned non-text information. References in the text to physical entities (for instance, a piece of equipment) are not in a format that can be interpreted by an expert system which is used to execute the knowledge base. Such an inference engine can only interpret defined process objects. The references to physical entities must therefore be linked to process objects, created in this phase, which can then be interpreted by the expert system.

Each text note generated in the consolidation phase is examined one at a time. The user must identify all references to physical entities (which may include pieces of equipment) that are listed in the text. The user must consider whether that physical entity has been previously referred to. Each reference to a physical entity must be associated with a generic group (called a "class") which must be created, or selected if it already exists. Each reference to a physical entity must be labelled with a process object name that will be used to refer to that particular object during this phase and in the knowledge base building process.

Each characteristic (for example, level, temperature, open-close) listed in the text note for a specific process object is identified as an attribute of that process object and also becomes an attribute of the class to which that process object belongs. A data type is defined for each attribute (for example, integer or floating point numeric numbers, logical, date).

If the text note refers to the value of an attribute of a process object in a qualitative term, then the attribute can be identified as one that can contain an imprecise term (for example, increasing fast, high or cold) which can take on a range of values with differing levels of confidence. Labels must be defined for attributes that are identified as ones that can contain a imprecise term. A specific range of values are associated with each such imprecise label.

As an illustration, in a note which contains a reference stating that the "level in a tank is high", the physical entity would be "tank". The first step would be creation of a generic group or class which could be called "tank". The physical entity being referred to could be labelled with a more specific process object name such as "water tank". The characteristic being described in the case (i.e., the "level") would become an "attribute" of the process object.

The datatype would be floating point and could be designated as a "fuzzy" type with a fuzzy term of "high". The value of high would be defined further as a specific range of values.

This approach is unique in the fact that it uses a top down approach, rather than the bottom up approach that is the norm in object oriented programming. In object oriented programming classes are defined first with all their attributes and objects are created from the defined classes. Objects created the conventional way inherit all the characteristics (attributes) of the class. In the approach utilized in the present invention, classes inherit the attributes of their member objects. The classes created in this phase can be used to create new objects.

Rule Building Phase

The process definition phase results in a database of process objects that refer to physical entities in the application's real world. During rule building these process objects are used in combination with functions, methods and operators to create individual rules that reason about situations in the real world that reflect the information on the process as gathered and consolidated in previous phases.

Each text note generated in the consolidation is examined one at a time. The user writes individual expressions based on each specific note.

Expressions related to problem identification, cause verification, opportunity identification and constraint verification are used as the premise (conditional) part of the rule.

Expressions related to corrective actions and optimization actions are used in the premise as well as in the conclusion (action) part of the rule.

The user has the option to define a custom message that will be displayed to the end-user when the rule is executed.

The collection of rules is structured using the prioritization as defined during the consolidation phase. Expressions are added to action rules to disable applicable problem and action rules while the current action is executed.

This phase results in a knowledge base which is in a form that can be interpreted by the expert systems inference engine. The resulting knowledge base ensures that predetermined objectives are met and that rules are executed in the most optimal manner.

The preferred embodiment of the present invention provides tools to assist in the ongoing maintenance and enhancement of the knowledge base. One important characteristic is that all changes are carefully logged. Another is that the user is given multiple ways to view the information being edited. A verification process can also check for missing information or conflicting entries. During and after knowledge base developments, a debug feature is used to test the rules which have been set.

A prototype of the preferred embodiment of the current invention has been developed and the Expert Optimizer is expected to be made commercially available by approximately December 1997. The Expert Optimizer was developed to interface with a commercially a available expert system which will also be concurrently available from Comdale Technologies (Canada) Inc. Although this description discusses the implementation of the present invention with reference to an expert system from Comdale, the concepts may be generically adapted to almost any rule-based expert system.

The various features and advantages of the present invention may be more readily understood with reference to the following detailed description of a typical use of the system taken in conjunction with the accompanying screen shots and descriptions relating to the preferred embodiment of the present invention, wherein like reference numerals designate like structural elements:

Brief Description of the Drawings

Fig. 1.1 is the screen showing the Application Workspace from which a new knowledge base is created.

Fig. 1.2 is the screen in which the new application name is entered.

Fig. 1.3 is an information screen that is shown after a new application name is entered.

Fig. 1.4 is the screen used to ask the user regarding the objectives of a particular application.

Fig. 1.5 is the screen used to ask the user how information about the process can be obtained.

Fig. 1.6 is the screen used to ask the user if more than one domain expert will be interviewed.

Fig. 1.7 is the screen that is shown if the user responds that multiple experts will be interviewed.

Fig. 1.8 is the screen that is shown if the user responds that only one expert is being interviewed.

Fig. 1.9 is an information screen used to guide the user through the various phases of developing an expert system application.

Fig. 1.10 is an information screen which details the different steps in the development of an expert system application.

Fig. 2.1 is a screen which shows a selection menu which contains the different phases in the development of an expert system application.

Fig. 2.2 is a screen which is shown when a user selects "new" from the selection menu shown in Fig. 2.1.

Fig. 3.1 is an information screen which provides an explanation of upcoming steps.

Fig. 3.2 shows the first question of the interview.

Fig. 3.3 is an information screen which provides an explanation of upcoming steps.

Fig. 3.4 shows the screen used to ask the domain expert to describe how each problem is identified.

Fig. 3.5 is the screen used to allow the user to prioritize the problems.

Fig. 3.6 is a screen used to allow the user to select the next step.

Fig. 3.7 is the screen used to prompt the user to list the causes for each problem.

Fig. 3.8 shows the editor screen used to allow the user to enter causes.

Figs. 3.9 and 3.10 show the editor screens used to allow the user to enter the cause verification methods for each problem and to prompt the user to prioritize the causes of each problem.

Fig. 3.11 shows a selection screen from which the user can enter a corrective action for each cause.

Fig. 3.12 is an information screen.

Fig. 3.13 is the screen used to enter corrective action names.

Figs. 3.14 to 3.17 show the screens which allow the user to enter the different attributes of each action.

Figs. 3.18 and 3.19 show screens used to capture opportunity objectives.

Figs. 3.20 and 3.21 show screens used to capture opportunity identification methods.

Figs. 3.22 and 3.23 show screens used to capture constraints.

Figs. 3.24 and 3.25 show screens used to capture constraints verification methods.

Figs. 3.26 to 3.31 are screens used to capture optimization actions.

Fig. 4.1 shows a high level guide which indicates the progress made.

Fig. 4.2 shows detailed information about each process stabilization objective.

Fig. 4.3 shows the screen used to assist the user in constructing the consolidated descriptions.

Fig. 4.4 shows an expanded view of a consolidated description.

Figs. 4.5 to 4.8 show consolidated information regarding each action.

Fig. 4.9 is the screen used to select the prioritization step.

Fig. 4.10 shows the prioritization interface which provides a listing of all consolidated problems and consolidated opportunities.

Fig. 4.11 shows a grid or table view of the consolidated actions.

Fig. 4.12 shows a view description regarding a selected action.

Fig. 5.1 is the screen used to allow the user to choose to work with the wizard or to define objects for a particular note.

Fig. 5.2 is the screen shown when the New Object button is selected from Fig. 5.1.

Fig. 5.3 shows step 1 of the process object definition wizard.

Fig. 5.4 shows step 2 of the process object definition wizard.

Fig. 5.5 shows step 3 of the process object definition wizard.

Fig. 5.6 shows step 4 of the process object definition wizard.

Fig. 5.7 shows step 5 of the process object definition wizard.

Fig. 5.8 shows step 6 of the process object definition wizard.

Fig. 5.9 shows step 7 of the process object definition wizard.

Fig. 5.10 shows step 8 of the process object definition wizard.

Fig. 6.1 shows a selection menu for the rule builder phase.

Figs. 6.2 and 6.3 show introductory screens in the rule builder phase.

Fig. 6.4 shows step 1 of the rule building phase.

Fig. 6.5 shows step 2 of the rule building phase.

Fig. 6.6 shows step 2a of the rule building phase.

Fig. 6.7 shows step 2b of the rule building phase.

Fig. 6.8 shows step 3 of the rule building phase.

Fig. 6.9 shows step 4 of the rule building phase.

Fig. 6.10 shows the screen displayed when the application is generating the knowledge base.

Figs. 7.1 to 7.13 show prototypes of the editor screens provided in the maintenance portion of the preferred embodiment and are used to allow the user to maintain the data directly.

With reference to the drawings, the following is an illustrative approach to an application using the present invention.

Setup

A user will start a new Expert Optimizer application (i.e., new expert system knowledge base) by doing a right mouse click on the SEO branch in the treeview of the Inventory Tab in the Application Workspace (Fig. 1.1). This will present a pop-up menu where the user selects new application.

This will bring the SEO Tab in front and startup the setup wizard.

The setup wizard will guide the user through a few questions that pertain to the application and will give the user background information with regards to the development of an expert system application.

The user enters the application name in the screen shown in Fig. 1.2.

Information screen shown in Fig. 1.3 will then be displayed.

The user is asked to enter the objectives of the particular expert system application in the screen shown in Fig. 1.4. The objective: "Stabilize Process" is hardcoded, Other application specific, more business/management oriented objectives can be entered by the user. The user can get advice with regards to formulation of the objectives by clicking on the "Online Advisor" button.

For a successful implementation it is essential that the user is familiar with the process of the expert system application, in the screen shown in Fig. 1.5 the user is advised in which ways information about the process can be obtained. Again, the Online Advisor button gives more details on the subject.

The user is asked if different domain experts will be interviewed in the screen shown in Fig. 1.6. If the user is the expert and will not be interviewing other domain experts, the information gathered during the information gathering phase will be consolidated without going through the consolidation phase. The Online advisor button gives more details on the subject.

If the user responds that he or she is interviewing different experts, then the screen shown in Fig. 1.7 is displayed. Interviewing procedures and techniques are explained. The Online Advisor button gives access to more advice on the subject.

If the user responds that there will only be one expert interviewed then the screen in Fig. 1.8 is displayed. The Online Adviser button gives access to more advice on the subject.

The information screen in Fig. 1.9 will then be displayed. The SEO will guide the user through the different phases of expert system development. One item that is out of the scope of the SEO is the configuration of the interface with the host system. In this screen the user is advised that this is a task that he will have to do separately from the application development.

The information screen in Fig. 1.10 will then be displayed. This is the last screen of this wizard and details the different steps in the development and how to access these. The Online Advisor button gives access to more advice on the subject and can be accessed by selecting another Tab in the Application workspace.

After successfully completing the Setup wizard, the tree in the treeview of the SEO Tab will display the following:

+SEO

+Application Name
- Interviews
- Consolidated Expertise

A window (entitled "Knowledge Book") will be opened displaying the different phases in the development process. The contents of this screen are shown in Fig. 2.1.

At this stage the user will only be able to select "Interviews".

The user will select "New" from the selection menu and define the new expert name in the "Expert Editor". This is shown in Fig. 2.2. From that editor the user can start the interviewing process by clicking on the button "Save & Start Interview". This will save the

information entered on this screen, close the Expert Editor window and open the first screen of the interview.

Information Gathering

The interview starts by asking questions pertaining to the objective "Stabilize Process".

Fig. 3.1 is an information screen giving the user an explanation on the steps that are coming. A checkbox on this screen allows the user to disable display of this screen when the interviewing phase is started subsequently. Activating the "Next" button on this screen will bring the user to the first question in the interview. This window will close when "Next" is activated.

Fig. 3.2 shows the first question of the interview. "Ask the expert to list each problem that can occur and upset process stability". The user will repeat the question listed to the domain expert and log the answer the user is giving in the description field. A short name shall be given to the problem listed and entered in the Problem Name field. The Problem Name field allows the user to open a dropdown list of previously mentioned problems: the reference list.

> The reference list allows the user (interviewer) to identify one problem raised by the expert currently being interviewed as being the same as a problem raised by another expert in a previous interview. The correct procedure to follow, which the user has been advised of in the previous screen, as well as during the setup wizard and is also repeated in the Online Advisor, is, that before identifying the problem mentioned by the current expert as being the same as a previously mentioned problem, the user (interviewer) has to make sure by checking this with the domain expert currently being interviewed. A reference list exists for all the items to follow (: problem names, problem identification method names, cause names (per problem), cause verification method names (per cause/per problem), corrective action names (per cause/per problem), opportunity names, opportunity identification name (per opportunity), constraint names (per opportunity), constraint verification methods (per opportunity/per constraint), optimization action names (per opportunity/per constraint)), the same procedure applies where reference lists are being used.

After the user enters the problem name and (optional) description, clicking the "Add" button will list the problem name listed in the problem name field in the tree that is displayed on the left of the window. The user can now enter a new problem name and new description. The user can select problem names in the tree, this will populate the "Problem Name" field with the name of the selected problem and the description field with the applicable description. Once listed in these fields, the user can modify (Apply will apply the modifications and move the problem back in the tree), or delete the selected problem. Clear will clear the Problem Name and Description fields.

The Online Advisor button gives access to a screen displaying more information on the problem. Typically the Online Advisor gives information relevant to the subject.

When the expert has listed all the problems the user can click the "Next" button to move to the next step.

Fig. 3.3 shows an information screen which gives the user an explanation on the steps that are coming. A checkbox on this screen allows the user to disable display of this screen when the interviewing phase is started subsequently. Activating the "Next" button on this screen will bring the user to the first question in the interview. This window will close when "Next" is activated.

For each problem the user (interviewer) asks the domain expert: to describe how the problem is identified. This is shown in Fig. 3.4. A name for the identification method is entered as well as a detailed description of how the domain expert identifies the problem exists.

The detailed description is mandatory. As the user clicks "Add" the name of the problem identification method is added to the tree displayed on the left, under the appropriate problem name. The user selects another problem in the tree to list the identification methods for this problem.

When all the problems have identification methods, the user will click next to proceed to the next step. If the user clicks this button while not all of the problems have identification methods, the user will get a warning message that not all problems have an identification method defined.

The next step is to prioritize all the problems. This is shown in Fig. 3.5.

The user exits this screen by clicking "Finish" which will close the editor, save the information obtained in these three steps (list of problems, identification methods for each problem and problem prioritization) and will being the focus to the Knowledge Book window to enable the user to select the next step. See Fig. 3.6.

The next step will be to list the causes for each problem. See Fig. 3.7.

The next step "Cause List" will now display enabled for selection under the interview for this expert. When choosing "Cause List" from the Knowledge Book, the SEO will open a selection window that allows the user to select for which problem the causes will be listed. The user selects the problem and this will open the editors that allow entering of causes, as shown in Fig. 3.8, and cause verification methods, as shown in Fig. 3.9 and 3.10 for the selected problem, and the prioritization of the causes of each problem.

For entering the causes, cause verification methods and assigning the priority to the causes, the user proceeds in the same manner as for entering problems and problem

identification methods. The user interviews the expert always for the causes of a specific problem.

The information screens shown in Figs. 3.7 and 3.9 can be disabled.

When finished with the prioritization of the causes, the user is returned to the Knowledge book. As causes have been defined, the Corrective Actions step will be enabled for selection. The user will select the problem and causes for which to define the corrective actions through selection windows (first select problem then expand view to select the cause). See Fig. 3.11.

The selection of a cause will open the editor that will allow the user to enter the corrective actions for that particular cause.

The first screen is an informative screen, shown in Fig. 3.12. This screen can be disabled. The next window (shown in Fig. 3.13) is used by the expert to enter the corrective actions name only, no description. When the user has listed all the actions, the "Next" button will bring the following step.

The following step is a window containing a tabbed control which allows the user to enter the different attributes of the action. The tabs are: Actions (shown in Fig. 3.14), Conditions (shown in Fig. 3.15), Frequency (shown in Fig. 3.16) and Additional Action (shown in Fig. 3.17). The user proceeds with entering the information for the selected action and clicks apply to associate these definitions to the selected action. The user can quickly move to another corrective action listed in the tree by selecting the corrective action in the tree.

"Finish" will save this information, close the window and return focus to the Knowledge Book.

The steps described above are repeated for other objectives. These objectives are user defined and the user will be able to select the sequence in which the objectives are dealt with in the interview.

For the objective "Stabilize Process" the questions are focussed around:

Problem
Problem identification method
Causes
Cause verification methods
Corrective Actions

For all other objectives, which are "Optimization" objectives, the questions focus at:

Opportunity (See Figs. 3.18 and 3.19)
Opportunity identification method (see Figs. 3.20 and 3.21)

Constraints (see Figs. 3.22 and 3.23)
Constraints verification method (see Figs. 3.24 and 3.25)
Optimization Actions (see Figs. 3.26 and 3.31)

When all objectives have been submitted to these questions, the interview is completed. The user can start as many interviews as wanted.

Consolidation

The next phase in the development of the expert system application is to consolidate the gathered information.

Again the Knowledge Book will guide the user through this process and will only allow the user to access the next available steps.

Fig. 4.1 displays the expanded view of the Knowledge Book where progress information is updated as progress is made.

Consolidation is started by consolidating all the problems pertaining to the objective "Stabilize Process". The consolidation interface as displayed below is for the consolidation of all the problems listed for the objective Process Stabilization.

The identical interface is used for the consolidation of causes (with the exception of displaying Objective: Process Stabilization AND the specific problem of the cause and the text on the buttons: consolidate identification will read: consolidate verification, consolidate cause list will read: consolidate actions).

Also, the identical interface is used for the consolidation of opportunities (with the exception of displaying the applicable objective and the text on the button, consolidate cause list will read: consolidate constraints list).

Also, the identical is used for the consolidation of constraints (with the exception of displaying applicable objective AND the specific opportunity of the constraint and the text on the buttons: consolidate identification will read: consolidate verification, consolidate constraint list will read: consolidate actions).

This window can be expanded by clicking on the ▼ arrow in the lower right corner. The window will then become larger and will be able to display detailed information about the items selected in the grid on the left side of the editor (select an item in the grid to display below). See Fig. 4.2.

The user creates consolidated problems by associating problems listed in the grid on the left side (select the problem(s), click on the ">" - button). The selected problems will then populate the grid on the right side and will display in a different colour in the grid on the left side. Once associated, the problem in the left grid becomes unavailable for selection.

As association can be "undone" by selecting the item in the right grid and clocking the "<" - button.

If the user considers a problem listed in the left grid to be irrelevant for the application, this problem can be ignored by clocking on the "Ignore" button while the problem is selected.

Once a problem is defined ignored, this problem can be re-activated by clicking the "Re-activate" button.

The Online Advisor button will give the user advice referring to the consolidation of the current items.

The "Consolidate Identification" button becomes enabled for selection once a new consolidated item is defined (a name has been given), problems have been assigned to the item and the "Apply" button has been activated. When activated, this button will open the editor to Consolidate the problem identification methods for the current consolidated problem.

The "Consolidated cause list" button becomes enabled for selection, once a new consolidated item is defined (a name has been given), problems have been assigned to the item and the "Apply" button has been activated. When activated, this button will open the editor to Consolidate the causes for the current consolidated problem.

The "OK" button will save the current selected consolidated item with its associations (when no associations are made, a warning message will appear and the save action will be aborted) and close the editor.

The "Apply" button will save the current selected consolidated item with its associations (when no associations are made, a warning message will appear and the apply action will be aborted), the window will be kept open with the current information.

The "Cancel" button will discard any changes that were done in this editor after the last save action.

The user can create a consolidated description by consulting the descriptions listed in the lower part of the window. The lower part of the window can be collapsed by activating the ▲ button in the upper right corner of that part of the window. Fee Fig. 4.3.

The editors for the consolidation of: problem identification methods, cause verification methods, opportunity verification methods and constraint verification methods have the same basic lay-out as the screen shown in Fig. 4.3. The main difference consists in the fact that the field to edit the description is larger. (The description in identification and verification methods is mandatory: a consolidated item cannot be saved without a description, the description for a problem name, cause name, opportunity name, constraint name is optional).

These editors do not provide an option to open another editor. Once the user is finished with the consolidation of an item, the "Apply" button will save the information in the screen and the user can consolidate another item in the left grid. See Fig. 4.4.

The "OK" button will save the information, close the editor and return focus to the window where the editor was called from.

The "Cancel" button will discard any changes that were done in this editor after the last save action.

The consolidation of the cause and the consolidation of the constraints have a button that gives access to the consolidation of the actions pertaining to that consolidated cause/constraint.

The consolidation editor for actions allows for consolidation of all facets of the actions.

The information regarding the facet of the action displayed in the lower part of the window (if the window is expanded) is the information regarding the tab that has the focus (e.g., if the TAB Process Conditions is in front, then the information pertaining to the process conditions is listed in the display fields in the lower part of the window.

The user has to consolidate all mandatory tabs (Actions, frequency) in order to successfully save the consolidated action, otherwise a warning message will appear and the save action (apply or OK) will be aborted.

The Online Advisor will display advice pertaining to the tab that has the focus (is displayed in front). See Figs. 4.5 to 4.8.

The next step in the consolidation consists of the prioritization of the problems, opportunities and causes. See Fig. 4.9.

Prioritization: The .. button will give access allowing the user to choose to prioritize the problems & opportunities, once these have been prioritized, the user can select to prioritize the causes for each problem.

Note that the problems and opportunities are prioritized regardless of the objective. Causes are prioritized per problem (from Knowledge Book - checklist - choose to prioritize causes, choose for which problem).

The prioritization interface provides a listview of all consolidated problems and all consolidated opportunities. The interface is the same as during the interview. Fee Fig. 4.10.

Initially, the order in which the problems are listed is based on the average priority calculated by using the priorities of the associated problems as listed by the experts, opportunities will be listed after the problems.

Example: If consolidated problem A is associated with:

Associated problem	Priority given by expert	Expert
Problem 1	3	A
Problem 5	7	B
Problem 3	2	D
Problem 7	1	F

Then the average priority of Problem A (3+7+2+1)/4= 13/4=3.25

The prioritized list will allow to list the "then find problem/opportunity" statements in the correct order in the strategy rule.

The last step in the consolidation is Actions Tuning. The interface will provide a (table) grid listing all the consolidated actions (corrective and optimization). The order in which the actions are listed follows the order of priority of the problems/opportunity and cause. See Fig. 4.11.

Only the fields displayed in white can be edited by the user. When the user disables an action, the wait time for the action disabling this action will be entered as default waiting time, this default can be changed by the user.

As shown in the example above, each action disables itself for the time as specified in the question: how long do you wait before performing the action again, this information is retrieved from consolidation of the action (tab frequency). This disable cannot be taken away. If the user changes the default wait time for an action as specified in the tab frequency, the information in the tab frequency will be updated with the time entered.

In the example the "user" has disabled Action 3 and Action 4 for when Action 1 is fired, Action 3 for the default disable period from Action 1:1200 seconds, Action 4 for the period of 600 seconds., the "user" has disabled Action 2 for a period of 800 seconds for when action 5 is true.

The column headers have a default width of 20 characters and the names of the actions will be wrapped. The user can resize column width as desired.

When creating the action rule the SEO generated statements will include:

1. A wait statement on the problem of which the action originates for the period of time as indicated in the above table. This will also prevent the cause rules for that problem to be fired. The execution of the KB will follow this order:

    - find problem with highest priority, if true:
    - find causes for this problem. Causes will be checked in order of priority as indicated in consolidation, if cause is true:

- find action for that rule, action will be checked in order of priority
- action rule is fired and puts a hold on all rules associated with this problem (other causes are not verified, most obvious/urgent has been acted on)
- find problem with next highest priority, etc.

2. Wait statements on other action rules as indicated in the "Actions Tuning" table each for the period of time as defined in the table.

View description will open a dialogue as shown in Fig 4.12.

When Actions Tuning is also completed, the consolidation phase is completed.

The next phase if the Process Object definition.

Process Object Definition

Process Object Definition is started from the Knowledge Book. The user selects Process Object Definition and is presented with a selection window. In the selection window, the user selects for which Consolidated Item Process objects will be defined next.

The Knowledge Book will bring the user to the screen shown in Fig. 5.1. From here the user can choose to work with the wizard or to define the objects for this note from here.

The button New Object will open a new line in the table (see Fig. 5.2). The buttons New Class, Net Attribute, New Fuzzy term will only be accessible when a process object has been selected.

A Process object with more than one Fuzzy will display .. indicating that there is more (see Sag_Mill_1.Horspower: has the Fuzzy terms: High, Increasing and Normal. (see Fig 5.3)

Columns can be resized by user.

Records can be sorted by clicking on column header.

Step 1 POW (see Fig 5.3).

Step 2:

Displays the already defined process objects for this project and the user can map selected equipment from the current note to items mentioned in this list. This step will NOT be displayed if there are no process objects defined (that will only be the first time the user runs the POW wizard and if no objects have been defined by another module).

This step 2, where the user can map a selected piece of equipment to an earlier defined process object, will save him to have to repeat the questions: What is the class (step 3) and

what is the specific name (step 4) for this particular object. Any object that is mapped in this step will not be listed in step 3 and 4. See Fig. 5.4.

Step 3 in POW - identify/create class. See Fig. 5.5.

Step 4 POW - create Process Object. See Fig. 5.6.

Step 5 in POW - assign attributes to process object & class of which process object is a member. See Fig. 5.7.

Step 6 in POW - identify data type of attribute. See Fig. 5.8.

Step 7 in POW - identify fuzzy terms. See Fig. 5.9.

Step 8 - label fuzz terms. See Fig. 5.10.

Add term button not available without selection of object that already has a fuzzy term defined.

Rule Builder

The rule builder is started from the SEO Knowledge Book or through the Explorer Treeview pop up action menu "Create ▸ Rule". When coming from the SEO Knowledge Book, the user will get to a menu where a selection can be made. Listed for selection are all the Problems and Opportunities for the problem domain. When the user selects one of these, another selection menu becomes available with all of the consolidated notes under that problem/opportunity. See Fig. 6.1.

The rule builder has the following steps:

Step 1: An introduction screen (can be disabled).

Step 2: One or two screens (depending whether the user is creating an identification/verification or action rule) where the expressions for the rule are build.

Step 3: Where the customized message is edited, and a time label defined.

Step 4: Where the entire rule (including the steps from SEO) is displayed. Rule *cannot* be edited.

The user will not be able to proceed with a next step if the expressions build will not parse. This applies to proceeding from step 2 → 3, 2a → 2b, 2b → 3, 3 → 4. See Figs. 6.2 and 6.3.

Finish will being the user back to where the Process Object Wizard was called from.

The next item in the Knowledge Book is the **Fuzzy Definition**. The user will be able to access the fuzzy wizard for each fuzzy term identified for the application.

Step 1 applies to all rules. See Fig. 6.4.

Step 2 applies to rules created from consolidated notes for Problem Identification, Opportunity Identification, Cause Verification, Constraint Verification. See Fig. 6.5.

Step 2a applies to rules created from consolidated notes for Corrective & Optimization Action. See Fig. 6.6.

Step 2b applies to rules created from consolidated notes for Corrective & Optimization Action. See Fig. 6.7.

Step 3 applies to all rules. See Fig. 6.8.

Default text messages:

- Problem rule: "Problem <replace with problem name> is true"
- Opportunity rule: "The opportunity <replace with opportunity name> exists"
- Cause Rule: "Cause <replace with cause name> is true"
- Constraint Rule: "Constraint <replace with constraint name> is true"
- Corrective Action Rule: "The corrective action <corrective action name> will be taken"
- Optimization Action Rule: "The optimization action <corrective action name> will be taken"

Step 4 applies to all rules. See Fig. 6.9.

Knowledge Base Creation

The Knowledge Base will be created when the user activates the button "Create KB" at the bottom of the Knowledge Book screen. It is when this button is activated that the software will create l-code: a separate file that the i/e runs.

As the creation of this file might take some time, a pop-up (dialog) box will appear, similar to the dialog box that is displayed when you are copying/moving files (with the flying pages). This dialog box will have a control that indicates the progress of the KB creation and will have a Cancel button. "Cancel" will abort the creation of the l-code file. See Fig. 6.10.

Maintenance

On the following pages are screen prototypes of the editors that will alow the user to maintain project data directly (without the rigid structure imposed by the Knowledge Book). See Figs. 7.1 to 7.13.

CLAIMS:

1. A methodology to establish a knowledge base for use in an expert system comprising:
   - means to gather information to form a knowledge base;
   - said gathering means including means to conduct structured interviews to obtain information from experts;
   - means to build rules for the use of said system to instruct operators.

2. A system as claimed in claim 1 including means to define each physical entity in terms of an object name, and means to associate each said object name with a class.

3. A system as claimed in claims 1 and 2 in which said system includes means to consolidate information from a plurality of experts into a common knowledge base.

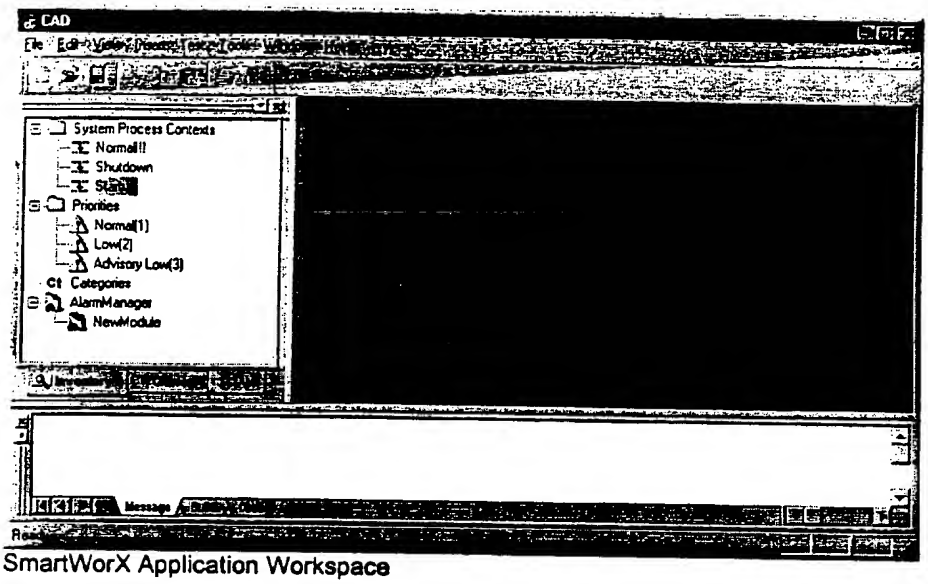
4. A system as claimed in claims 1, 2 and 3 in which said rules are employed to activate process control means.

5. A system as claimed in claims 1, 2 and 3 in which said means to conduct interviews is structured to allow the interview to be conducted by users without knowledge engineering ability.

6. A system as claimed in claims 1, 2 and 3 in which said methodology is computer implemented.

7. A system as claimed in claims 3, 4 and 5 in which said methodology is computer implemented.

Fig. 1.1



SmartWorX Application Workspace

Fig. 1.2

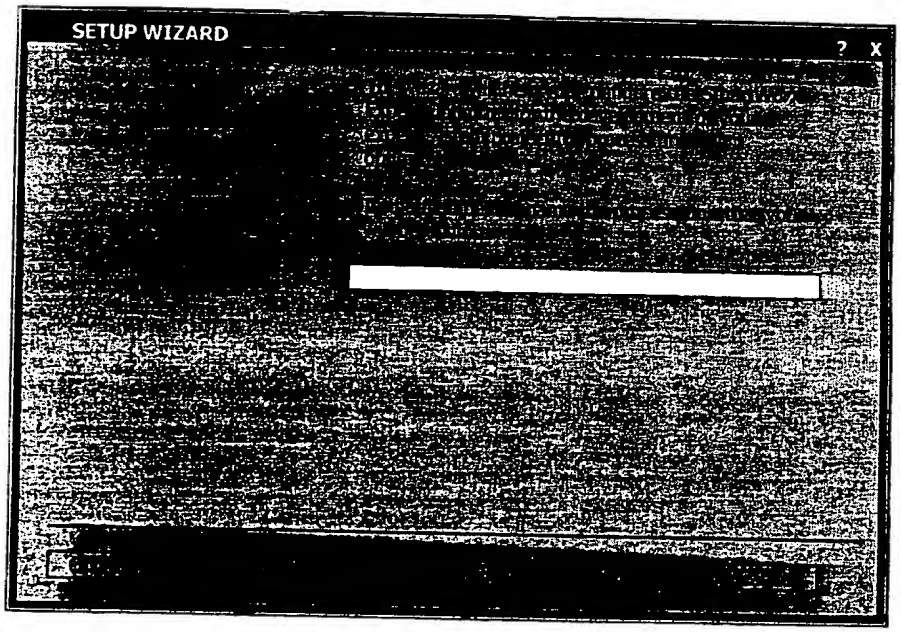


Fig. 1.3

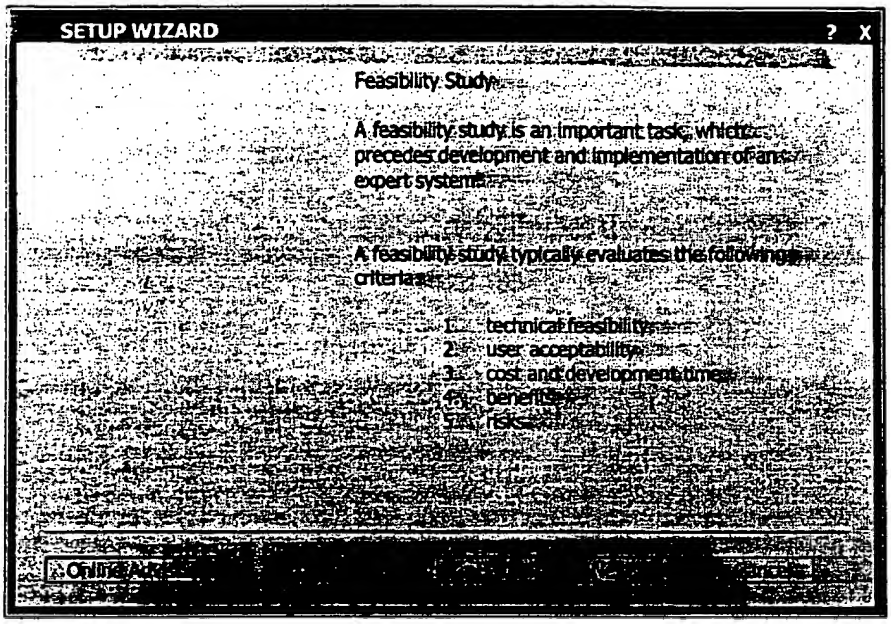

SETUP WIZARD
? X
Feasibility Study
A feasibility study is an important task, which precedes development and implementation of an expert system.
A feasibility study typically evaluates the following criteria:
1. technical feasibility
2. user acceptability
3. cost and development time
4. benefits
5. risks

Fig. 1.4

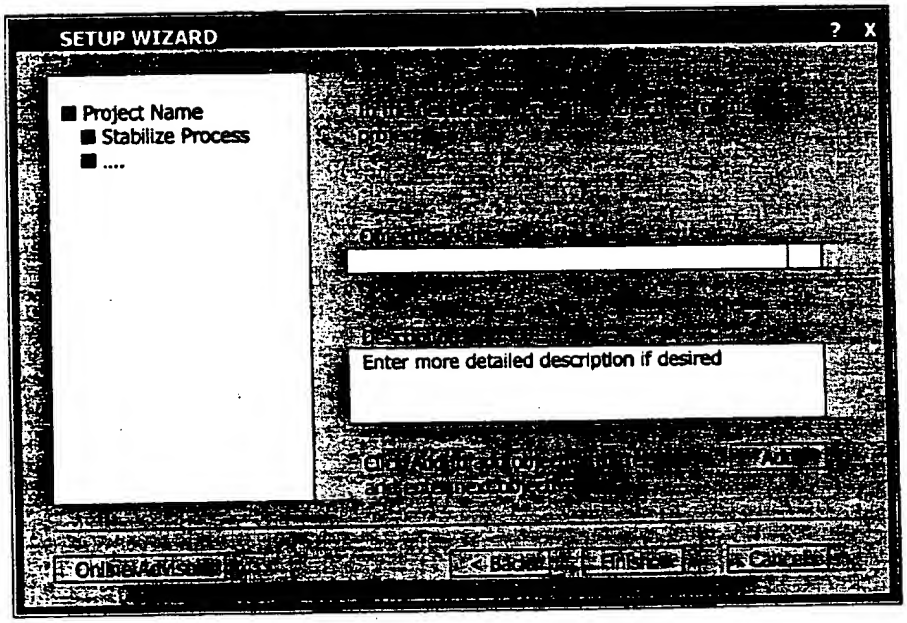

SETUP WIZARD
? X
Project Name
Stabilize Process
....
Enter more detailed description if desired

Fig. 1.5

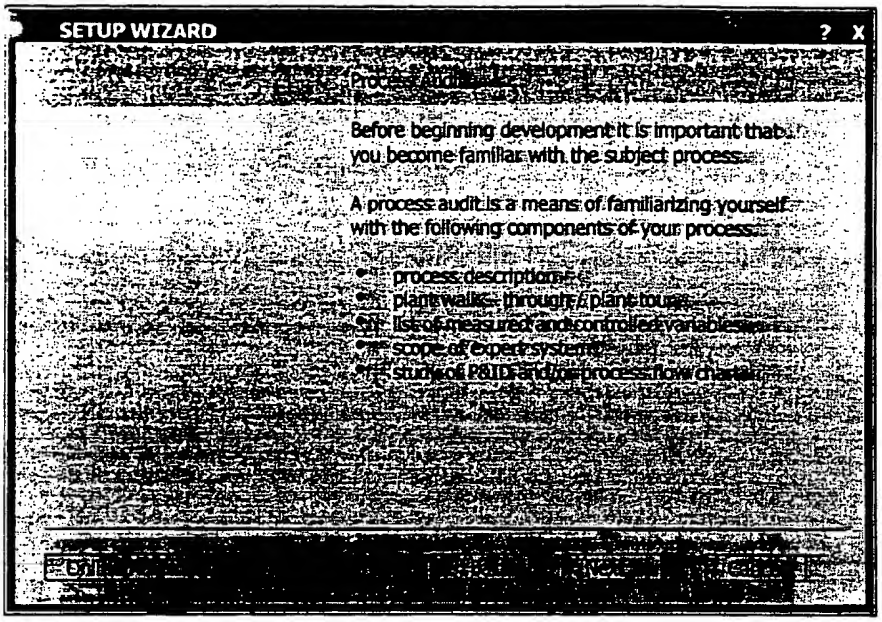

SETUP WIZARD
? X
Before beginning development it is important that
you become familiar with the subject process.
A process audit is a means of familiarizing yourself
with the following components of your process:

Fig. 1.6

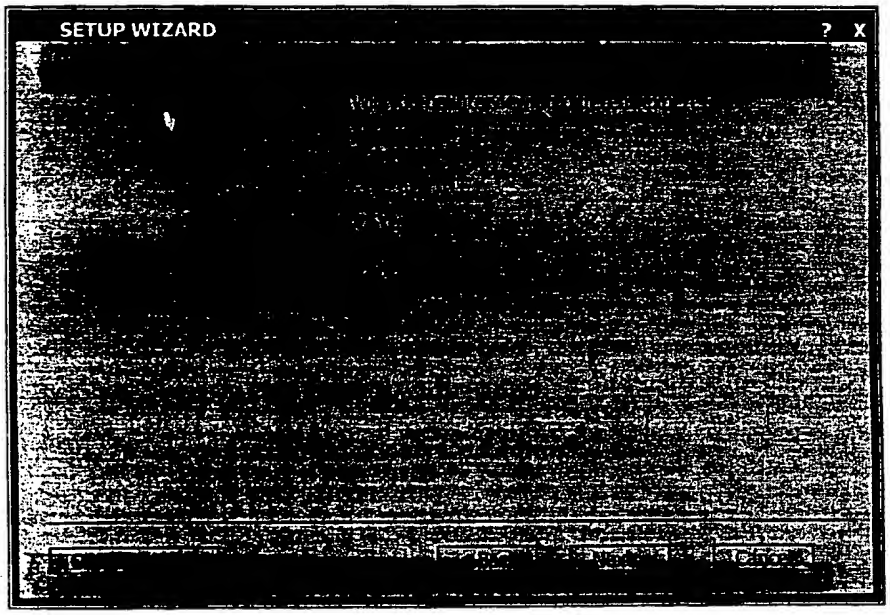

SETUP WIZARD
? X

Fig. 1.7

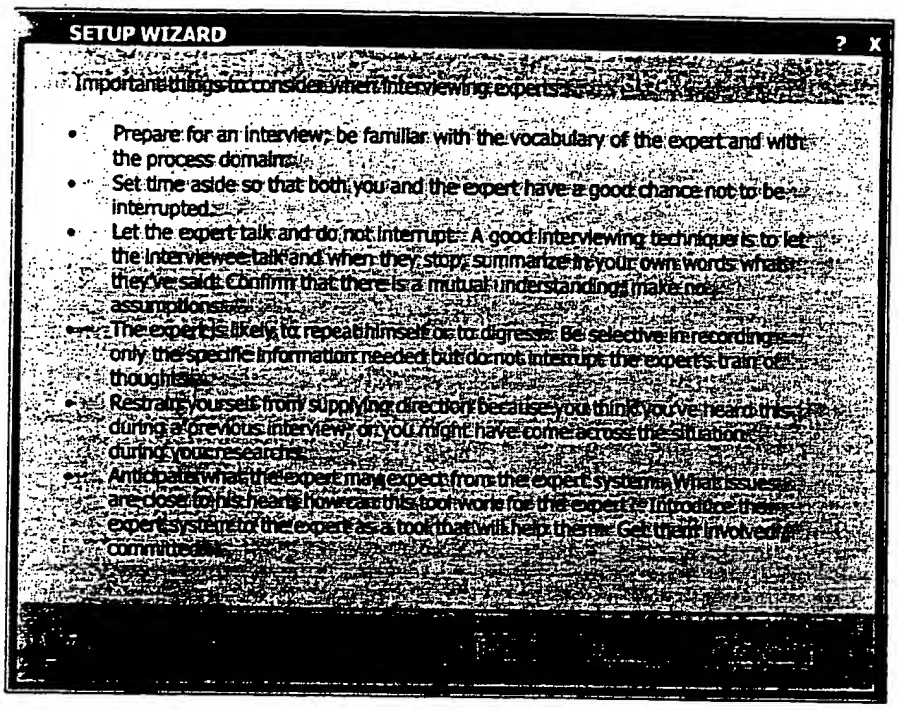

SETUP WIZARD
? X
Important things to consider when interviewing experts
Prepare for an interview; be familiar with the vocabulary of the expert and with the process domain.
Set time aside so that both you and the expert have a good chance not to be interrupted.
Let the expert talk and do not interrupt. A good interviewing technique is to let the interviewee talk and when they stop, summarize in your own words what they've said. Confirm that there is a mutual understanding. Make no assumptions.
The expert is likely to repeat himself or to digress. Be selective in recording only the specific information needed but do not interrupt the expert's train of thought.
Restrain yourself from supplying direction because you think you've heard this during a previous interview or you might have come across the situation during your research.
Anticipate what the expert may expect from the expert systems. What issues are close to his heart? How can this tool work for the expert? Introduce the expert system to the expert as a tool that will help them. Get them involved and committed.

Fig. 1.8

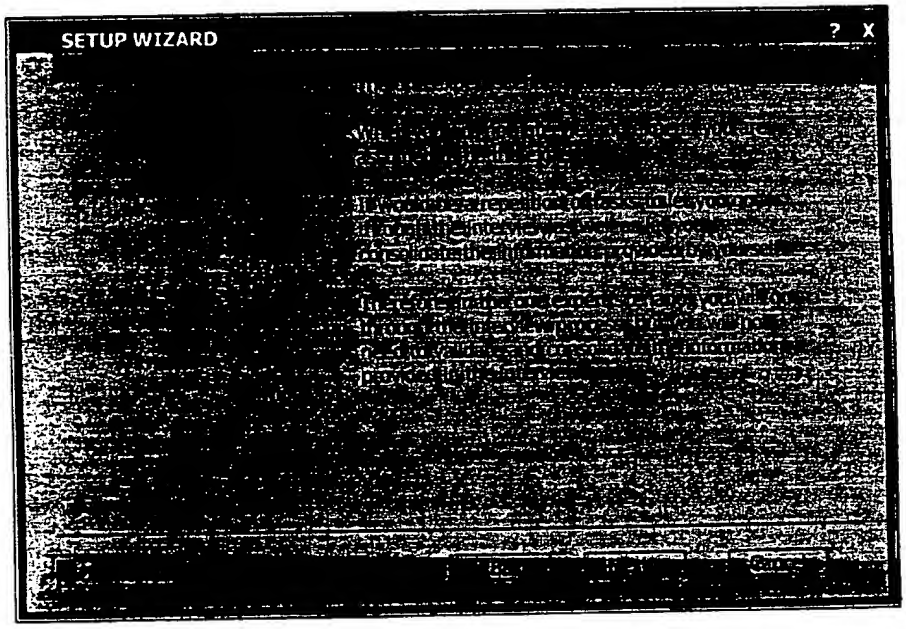

SETUP WIZARD
? X

Fig. 1.9

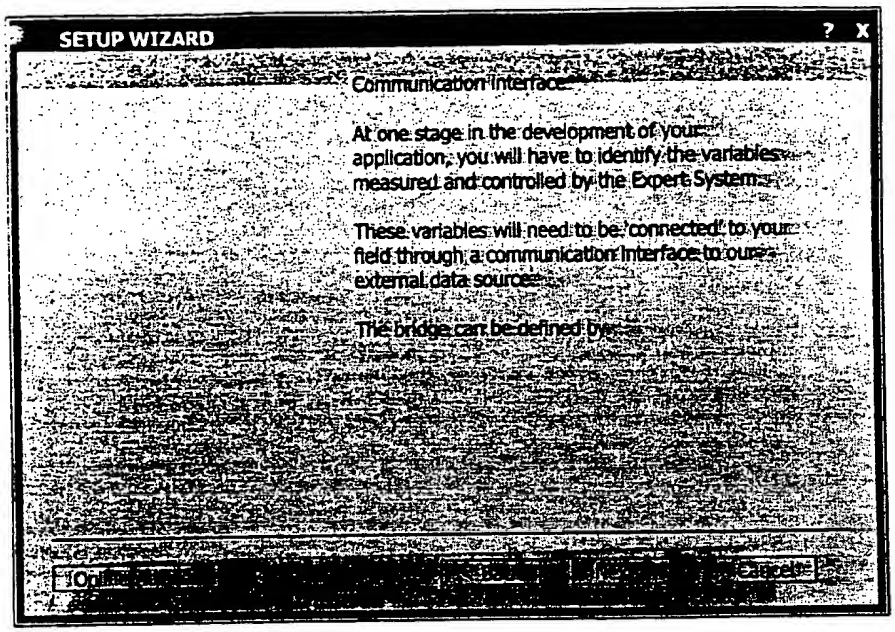


Fig. 1.10

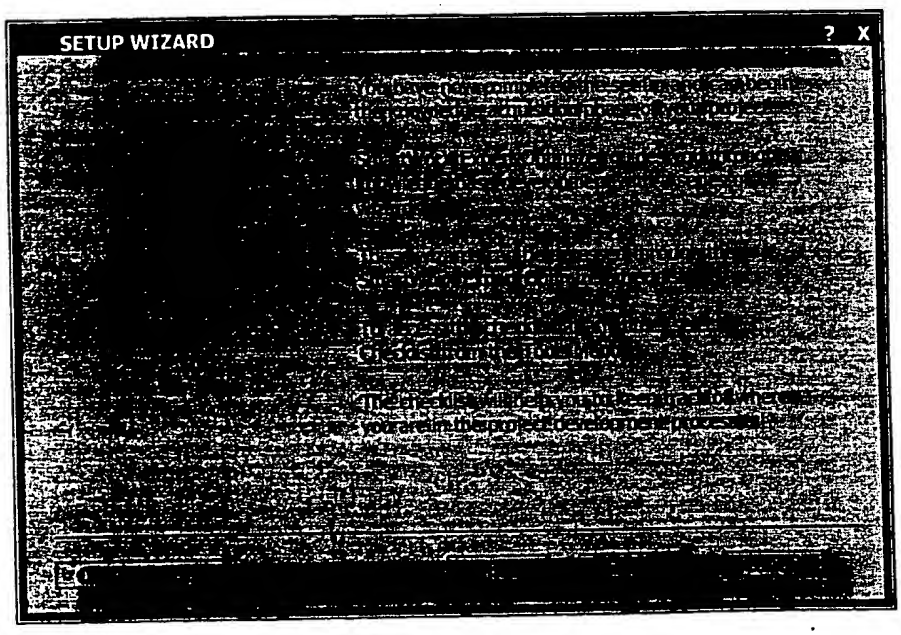


Fig. 2.1

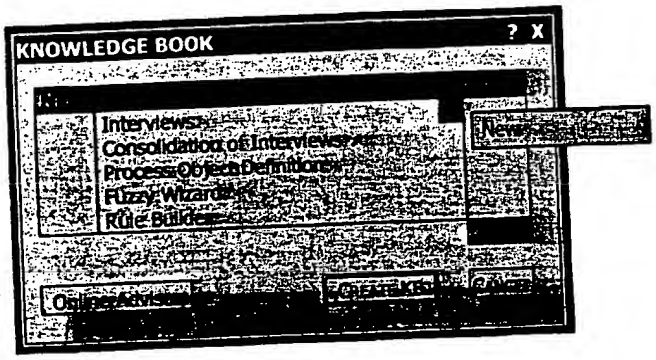

KNOWLEDGE BOOK
Interviews
Consolidation of Interviews
Process Object Definitions
Fuzzy Wizards
Rule Builder

Fig. 2.2

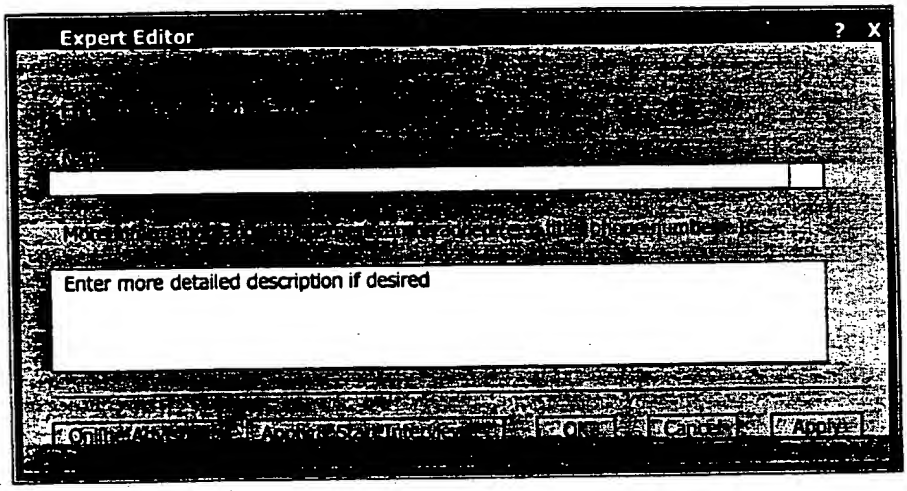

Expert Editor
Enter more detailed description if desired
OK
Cancel
Apply

Fig. 3.1

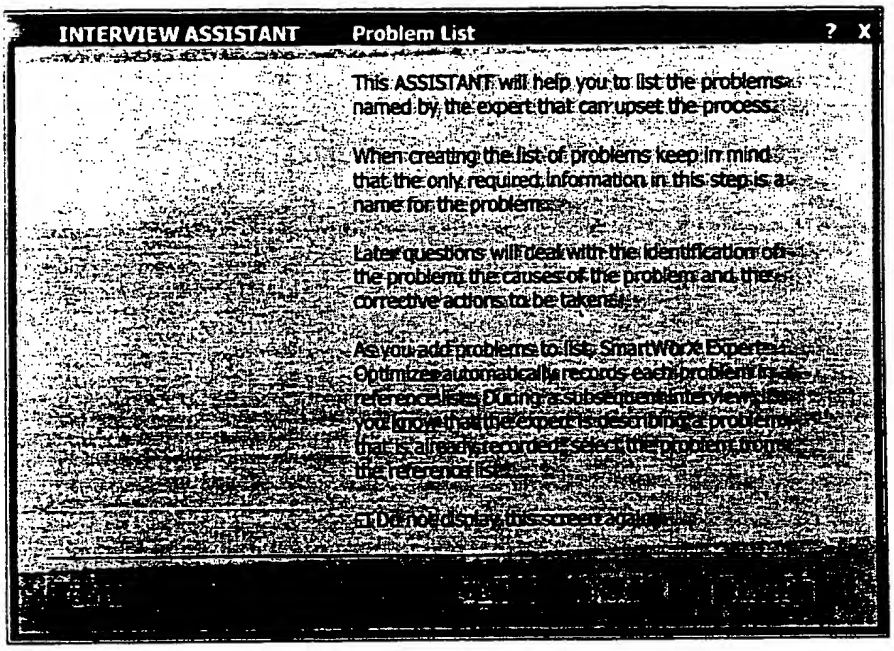

INTERVIEW ASSISTANT
Problem List
? X
This ASSISTANT will help you to list the problems named by the expert that can upset the process.
When creating the list of problems keep in mind that the only required information in this step is a name for the problems.
Later questions will deal with the identification of the problem, the causes of the problem and the corrective actions to be taken.
As you add problems to list, SmartWorx Expert Optimizer automatically records each problem in a reference list. During a subsequent interview, if you know that the expert is describing a problem that is already recorded, select the problem from the reference list.
Do not display this screen again

Fig. 3.2

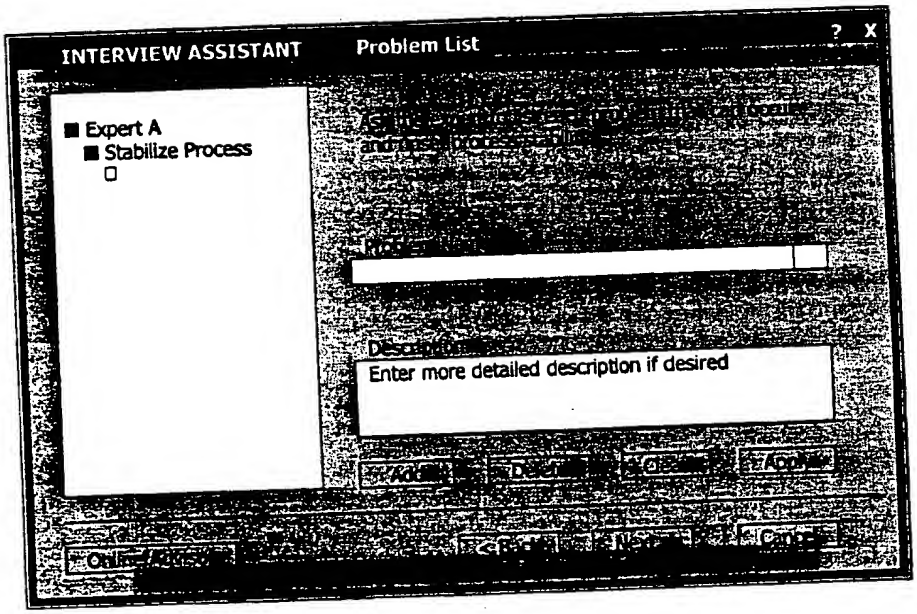

INTERVIEW ASSISTANT
Problem List
? X
Expert A
Stabilize Process
Enter more detailed description if desired

Fig. 3.3

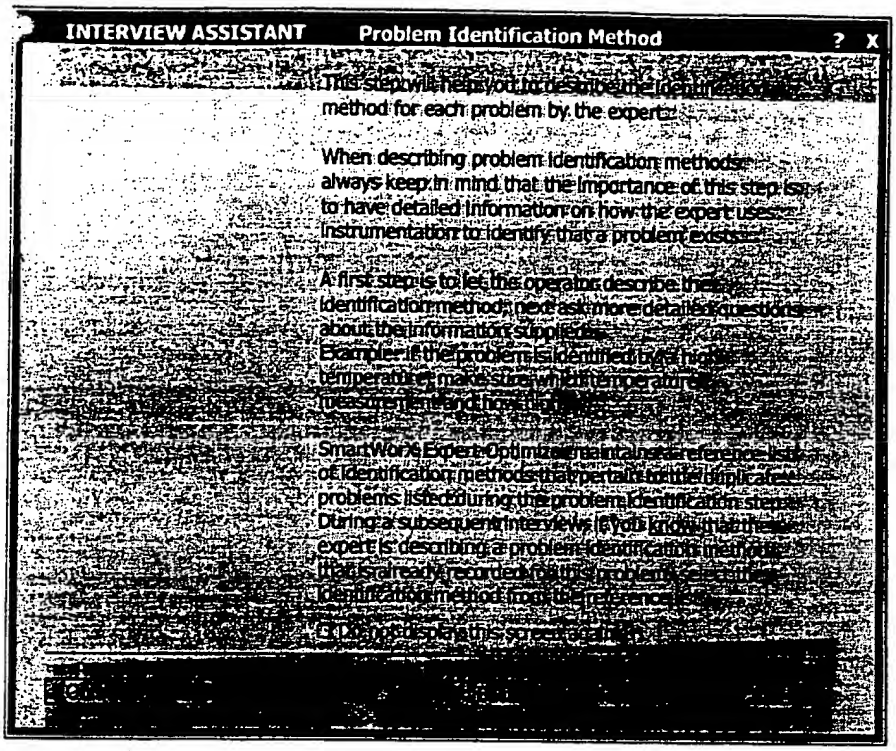

INTERVIEW ASSISTANT
Problem Identification Method
method for each problem by the expert.
When describing problem identification methods
always keep in mind that the importance of this step is
to have detailed information on how the expert uses
instrumentation to identify that a problem exists.
A first step is to let the operator describe the
identification method; next ask more detailed questions
about the information supplied.
Example: if the problem is identified by a
temperature, make sure that the measurement
SmartWorks Expert Optimizer maintains a reference list
of identification methods that pertain to the applicable
problems listed during the problem identification step.
During a subsequent interview, if you know that the
expert is describing a problem identification method
identification method from the reference list.

Fig. 3.4

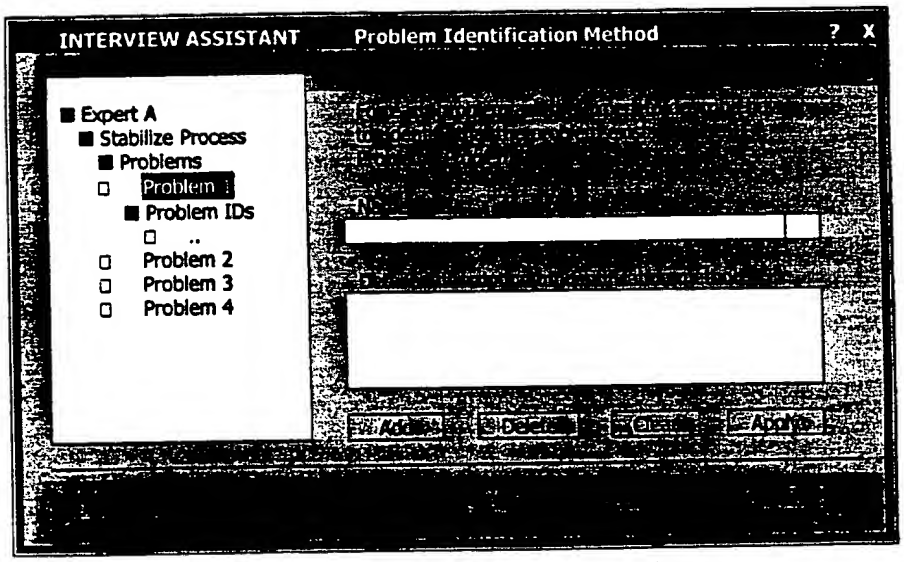

INTERVIEW ASSISTANT
Problem Identification Method
Expert A
Stabilize Process
Problems
Problem 1
Problem IDs
..
Problem 2
Problem 3
Problem 4
Apply

Fig. 3.5

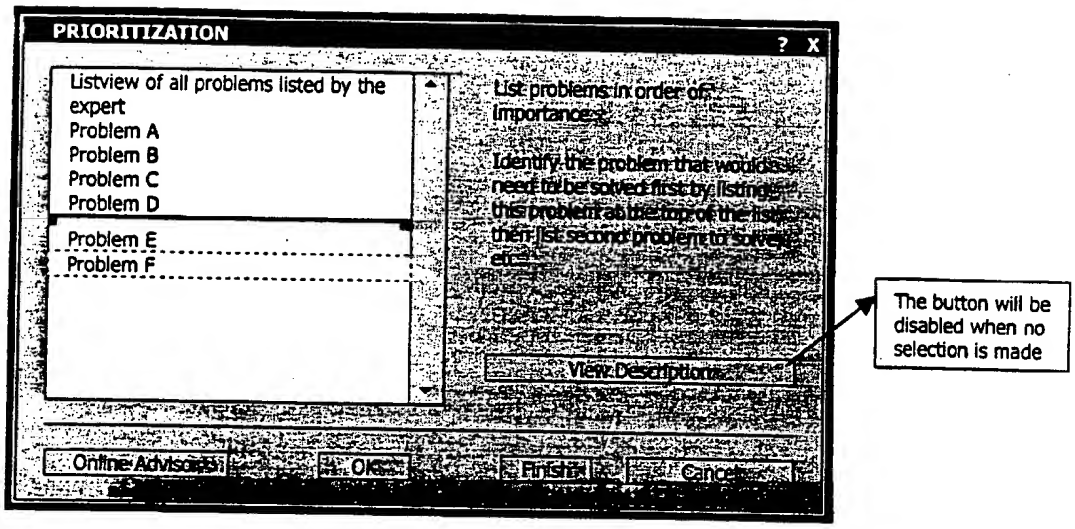

PRIORITIZATION
? X
Listview of all problems listed by the expert
Problem A
Problem B
Problem C
Problem D
Problem E
Problem F
List problems in order of importance:
Identify the problem that would need to be solved first by listing this problem at the top of the list, then list second problem to solve, etc.
View Description
Online Advisor
OK
Finish
Cancel
The button will be disabled when no selection is made

Fig. 3.6

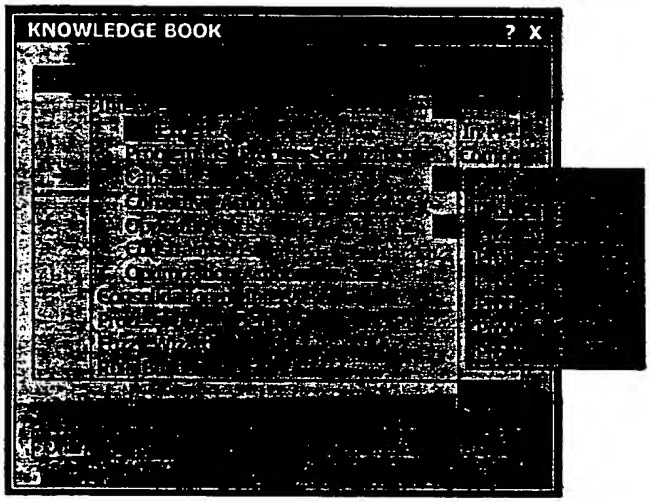

KNOWLEDGE BOOK
? X

Fig. 3.7

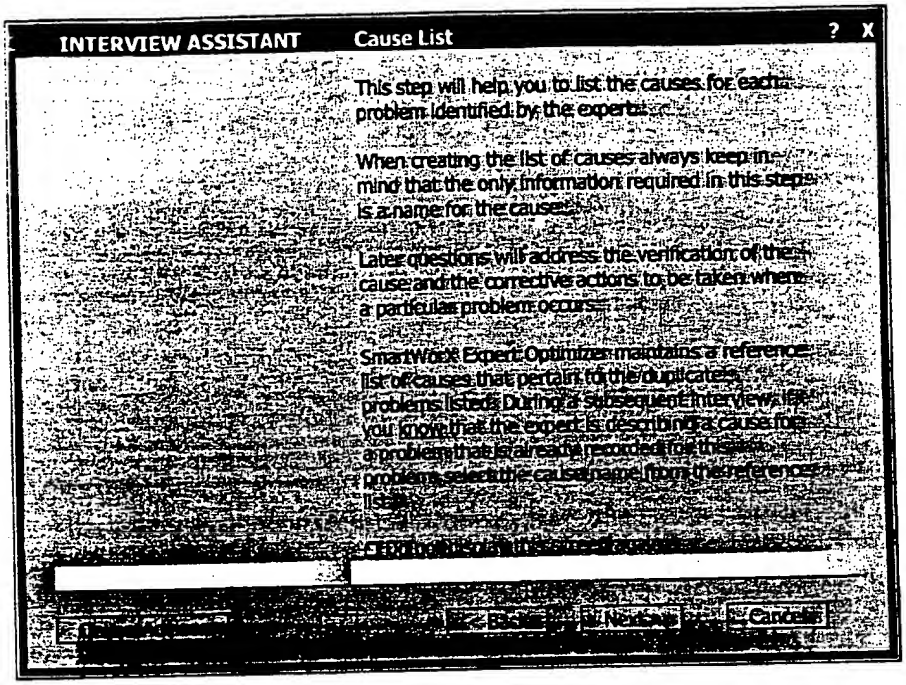

INTERVIEW ASSISTANT
Cause List
This step will help you to list the causes for each problem identified by the experts.
When creating the list of causes always keep in mind that the only information required in this step is a name for the causes.
Later questions will address the verification of the cause and the corrective actions to be taken when a particular problem occurs.
SmartWorx Expert Optimizer maintains a reference list of causes that pertain to the duplicates problems listed. During a subsequent interview, if you know that the expert is describing a cause for a problem that is already recorded for these problems, select the cause name from the reference list.
Back
Next
Cancel

Fig. 3.8

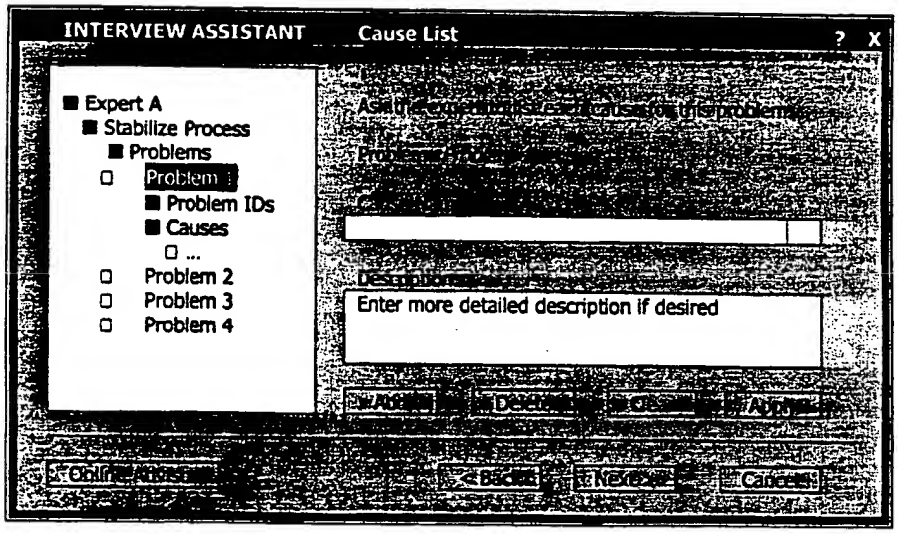

INTERVIEW ASSISTANT
Cause List
Expert A
Stabilize Process
Problems
Problem 1
Problem IDs
Causes
...
Problem 2
Problem 3
Problem 4
Enter more detailed description if desired
Back
Next
Cancel

Fig. 3.9

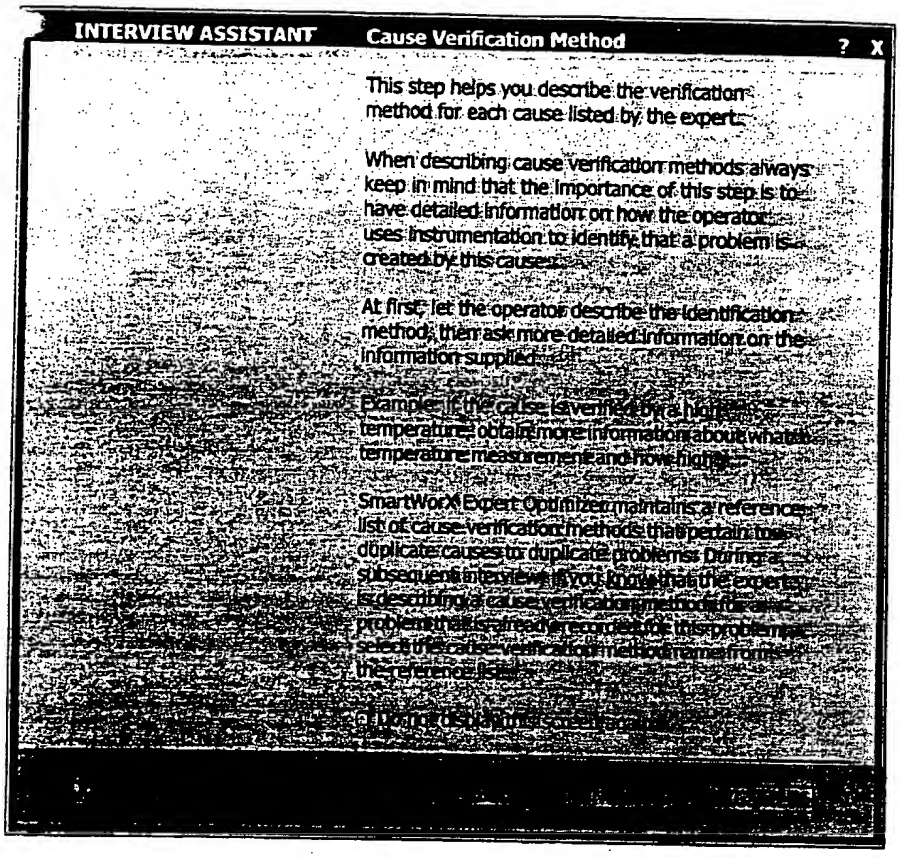
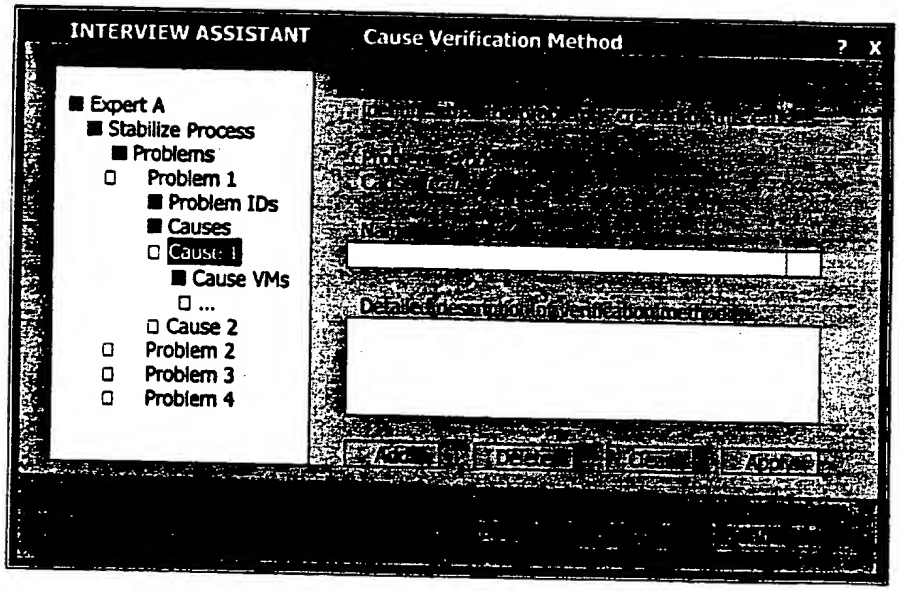


Fig. 3.10



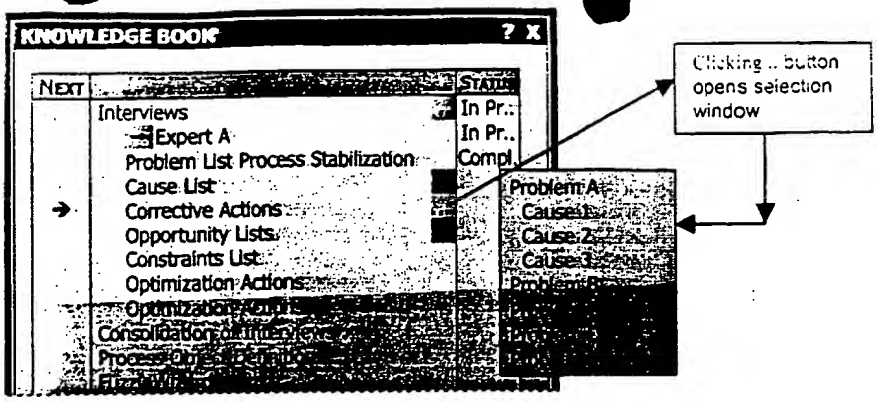


Fig. 3.12

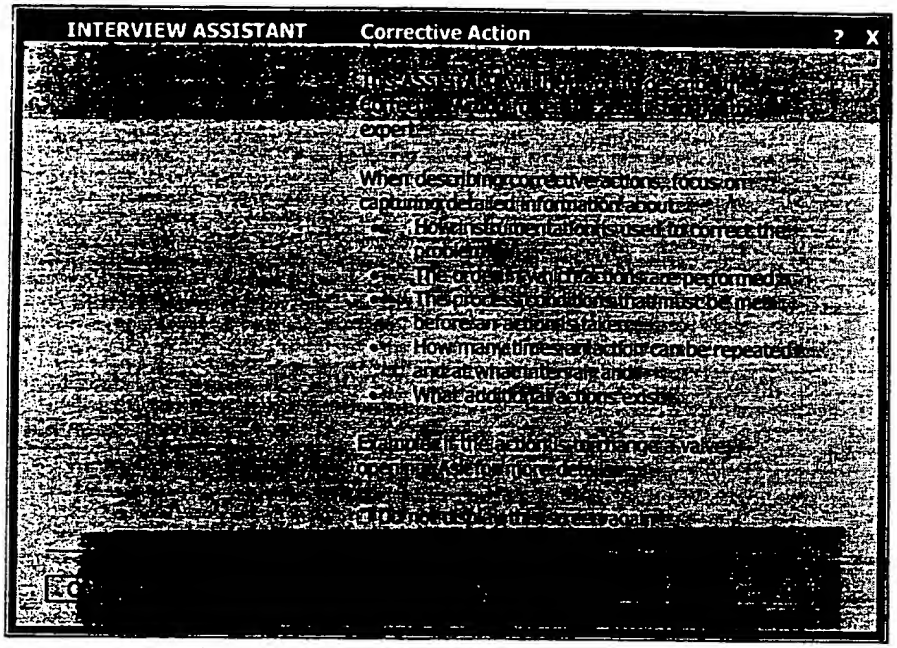


Fig. 3.13

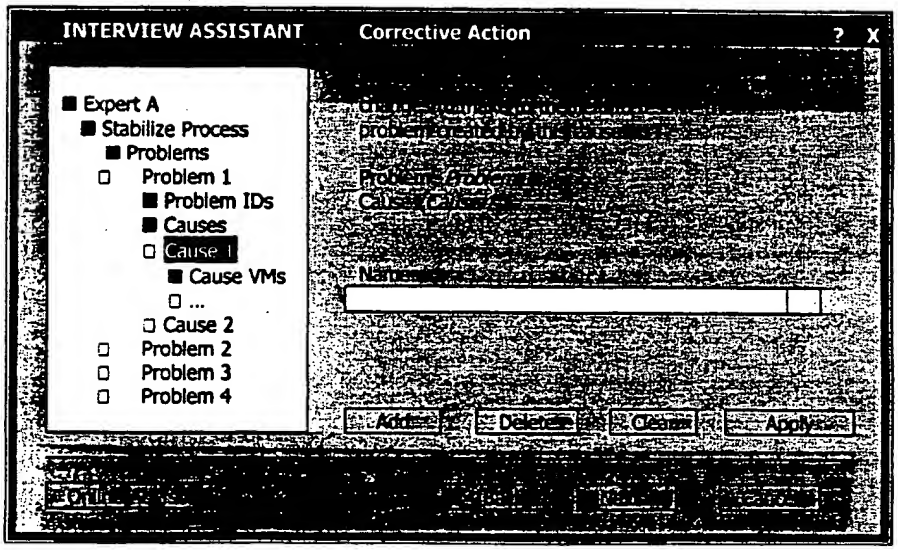


Fig. 3.14

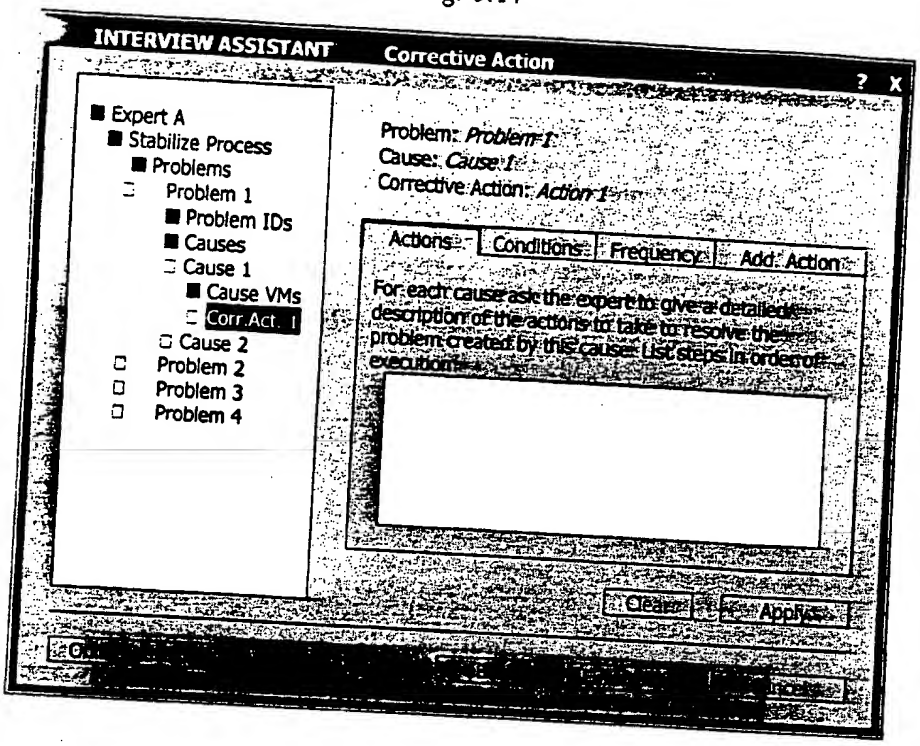


Fig. 3.15

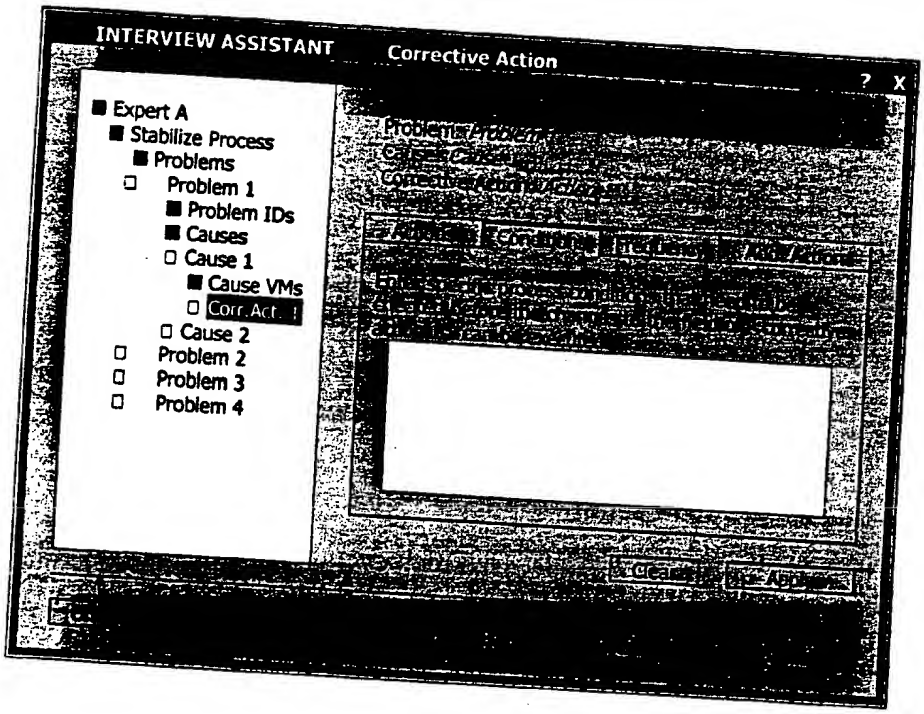


Fig. 3.16

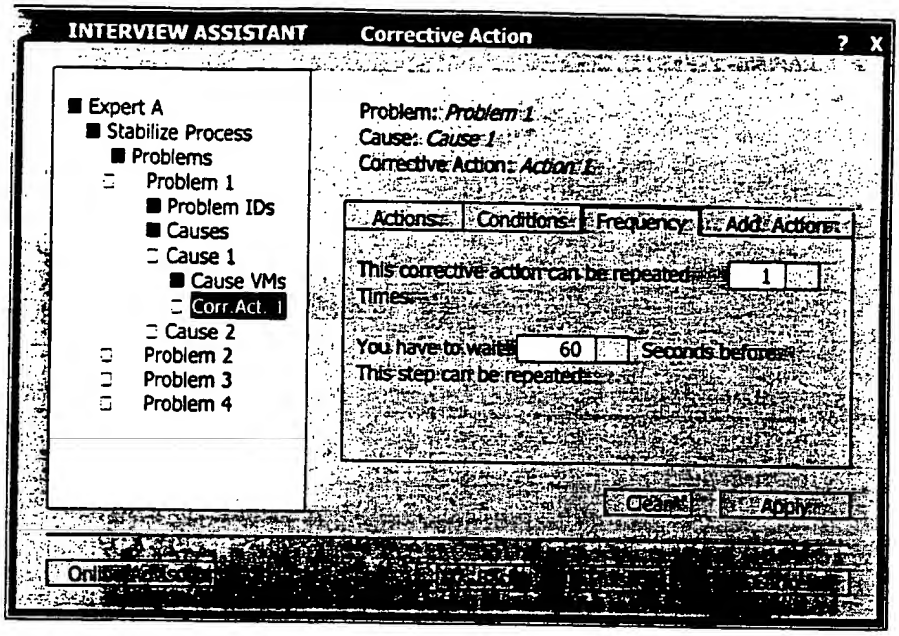


Fig. 3.17

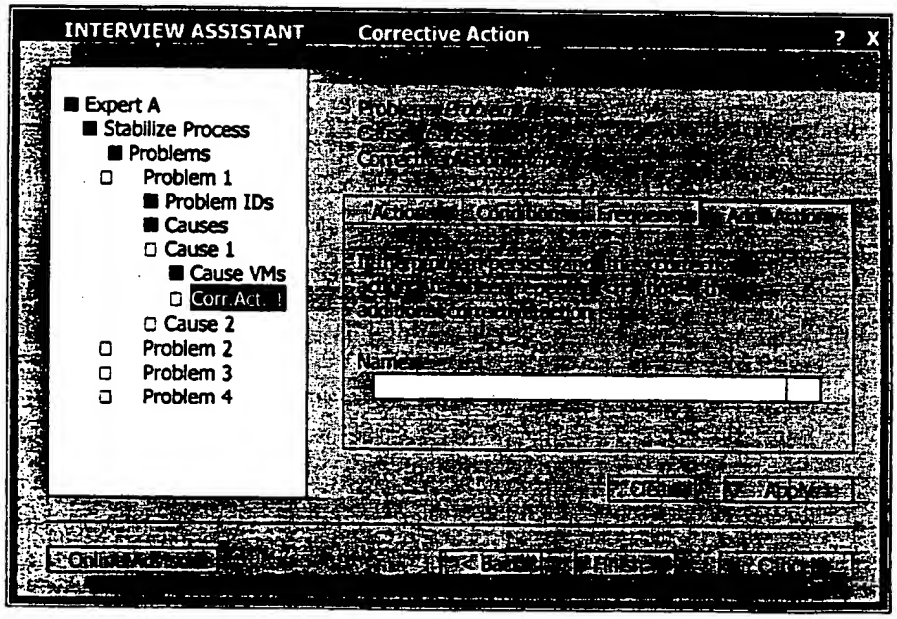


Fig. 3.18

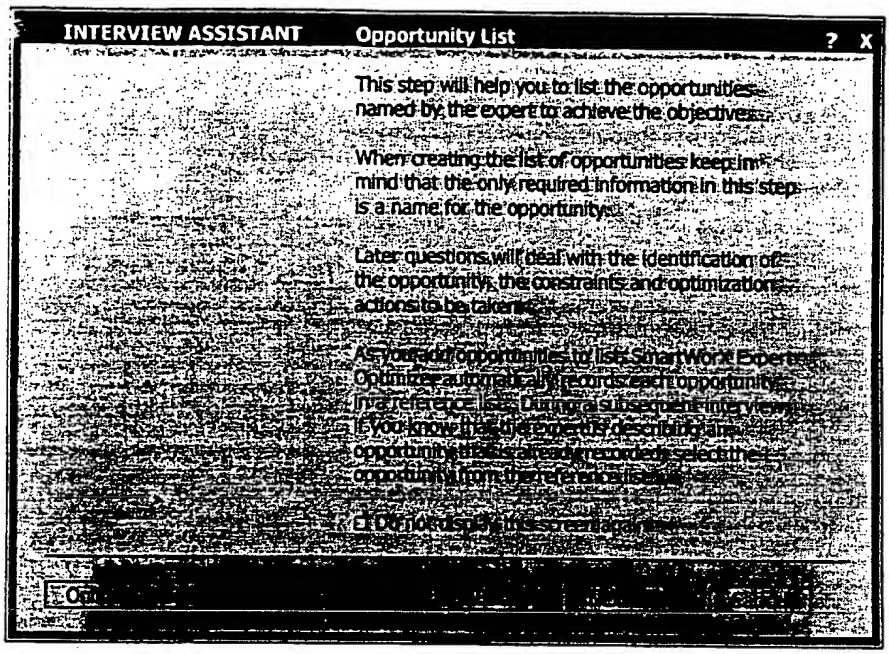


Fig. 3.19

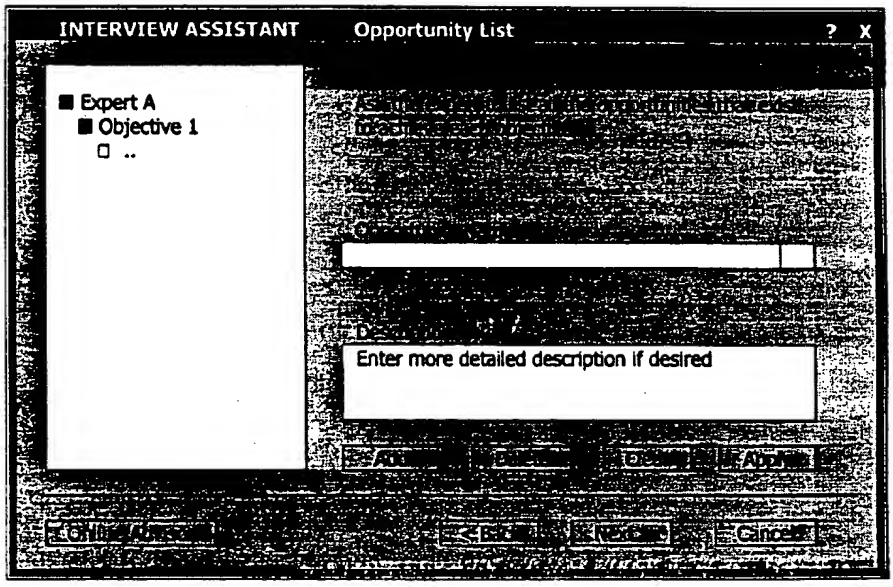


Fig. 3.20

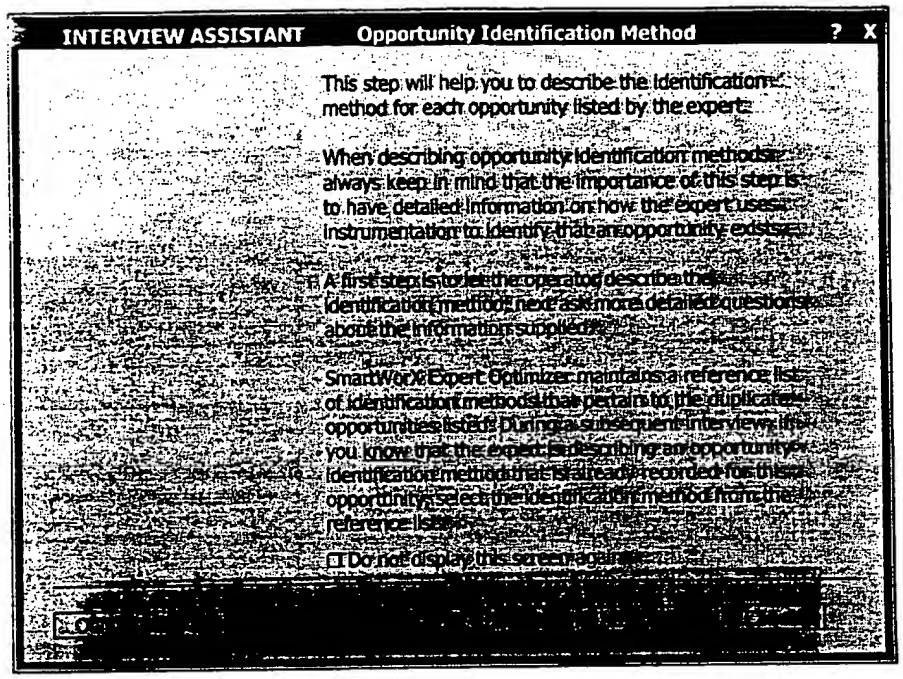


Fig. 3.21

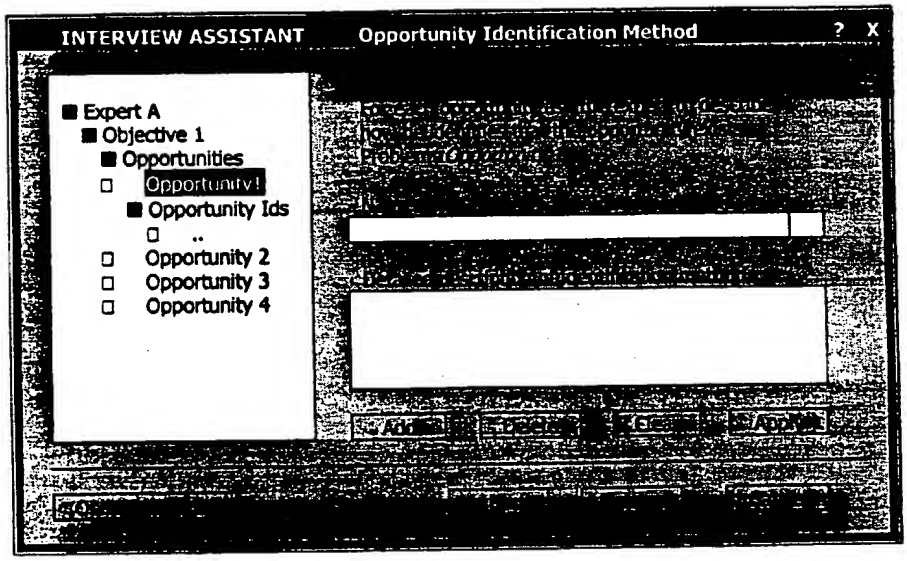


Fig. 3.22

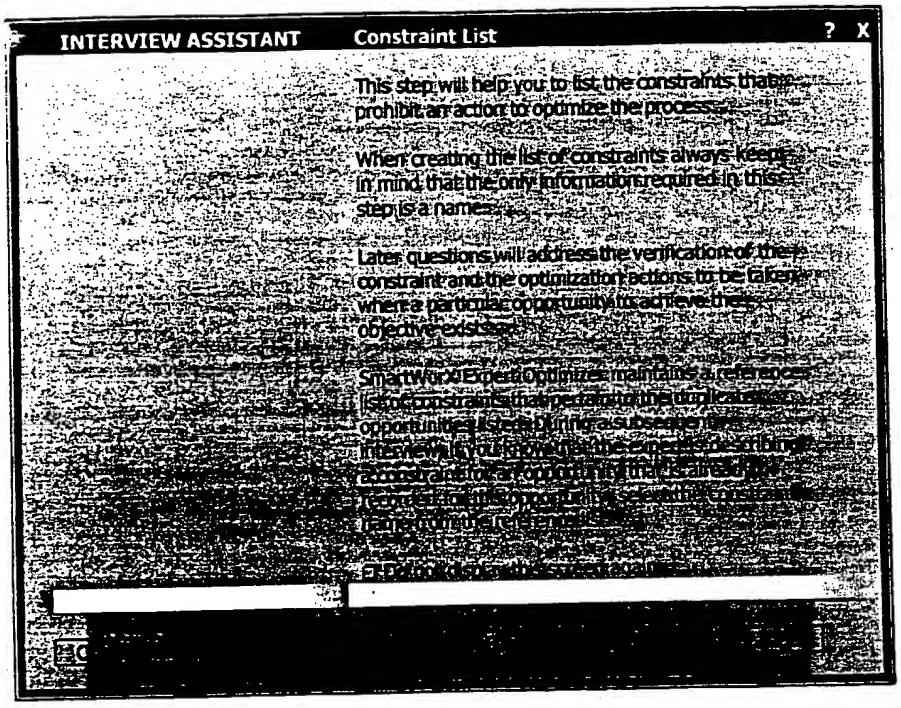


Fig. 3.23

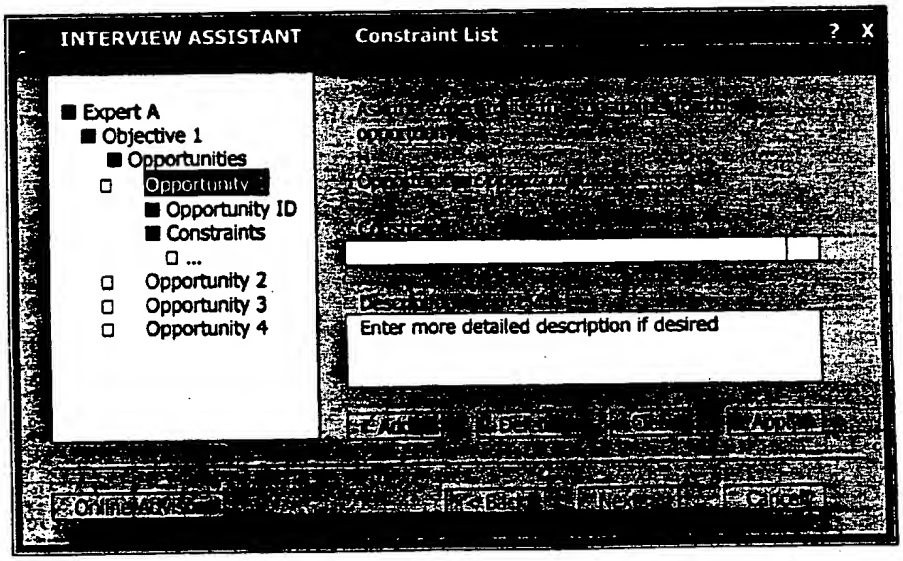


Fig. 3.24

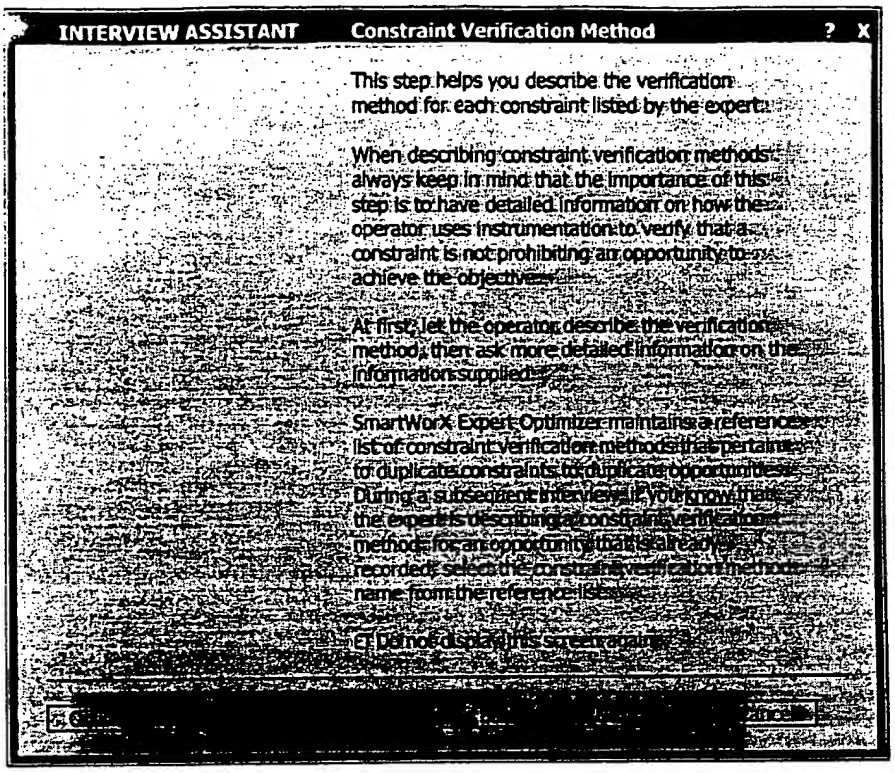


Fig. 3.25

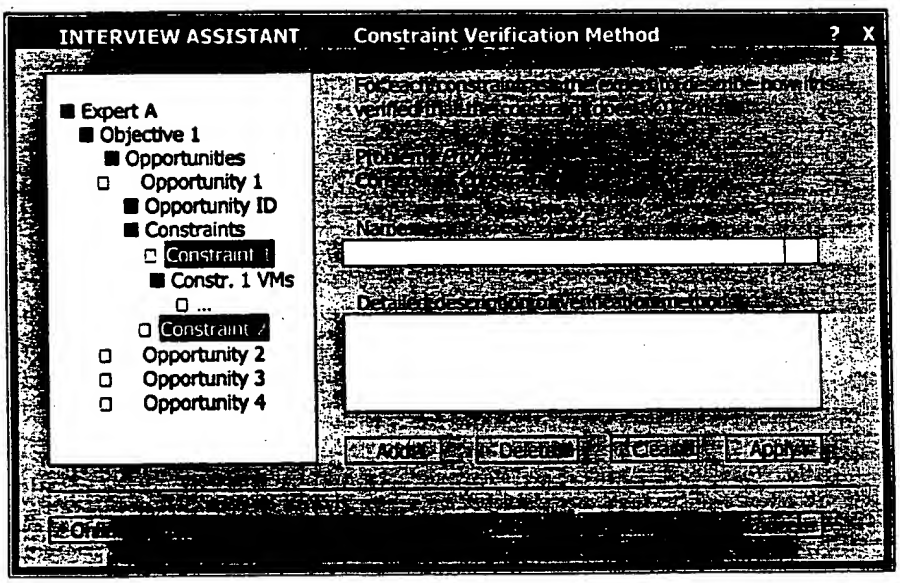


Fig. 3.26

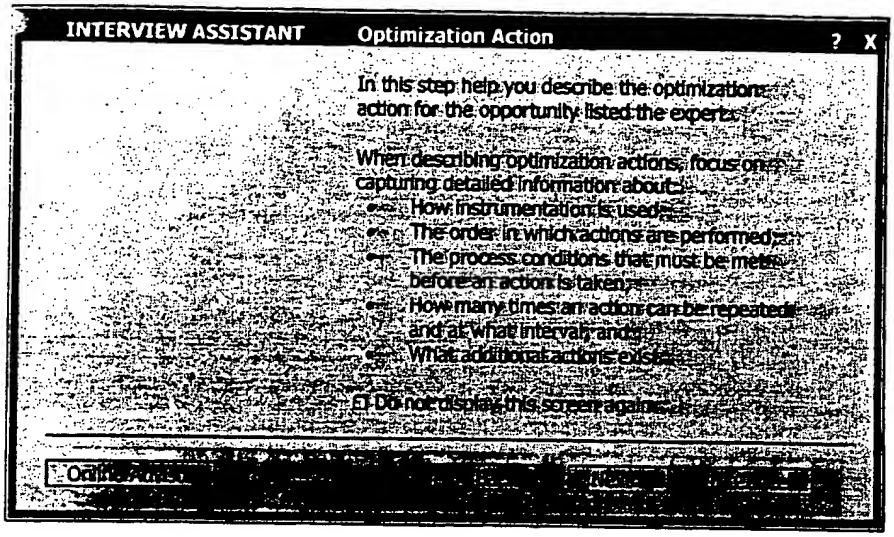


Fig. 3.27

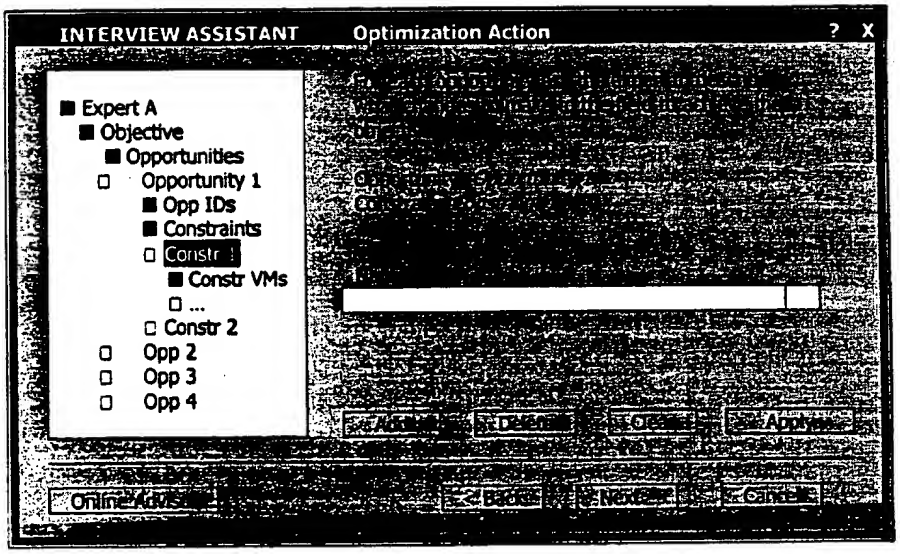


Fig. 3.28

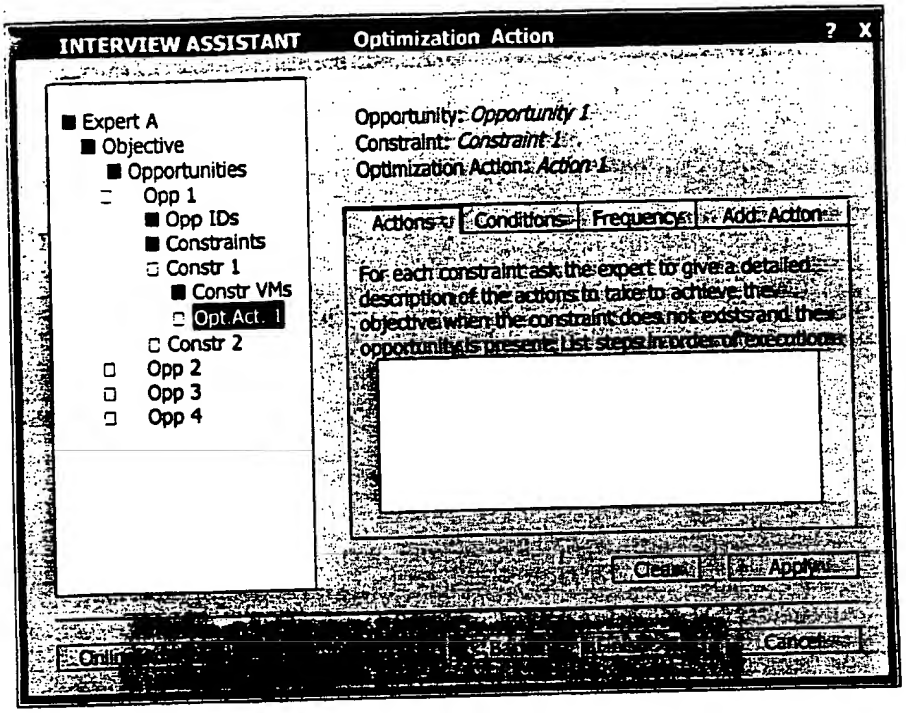


Fig. 3.29

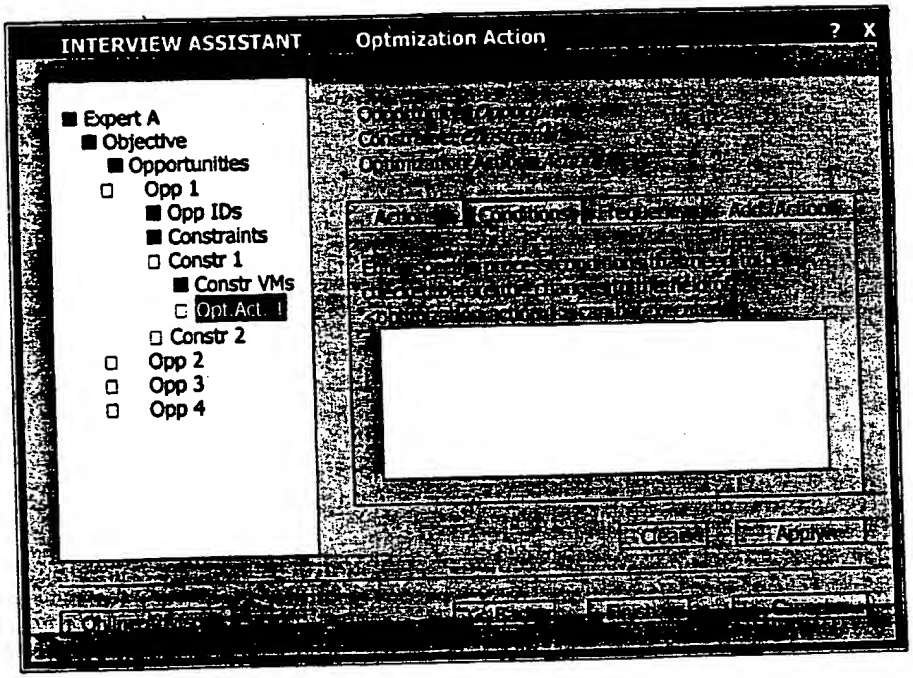


Fig. 3.30

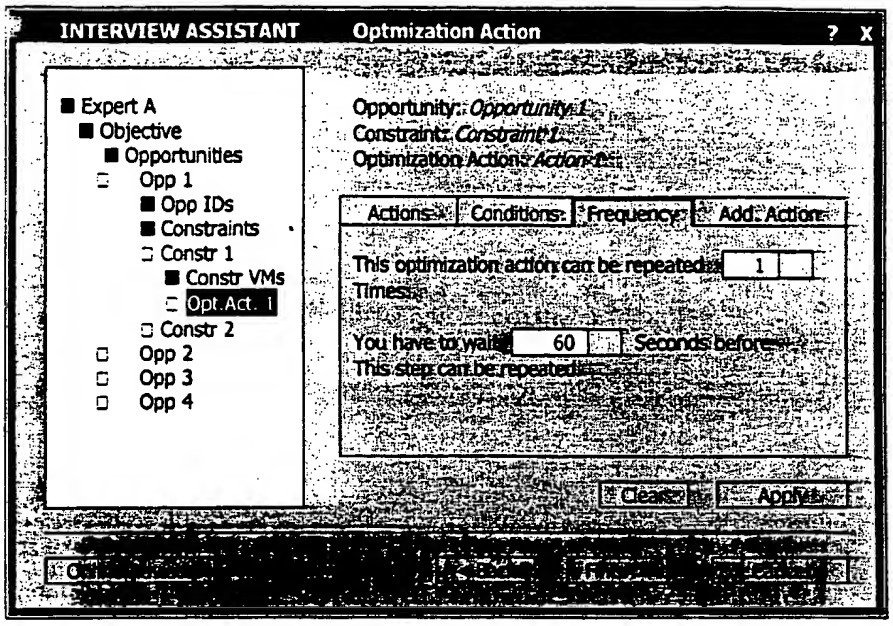


Fig. 3.31

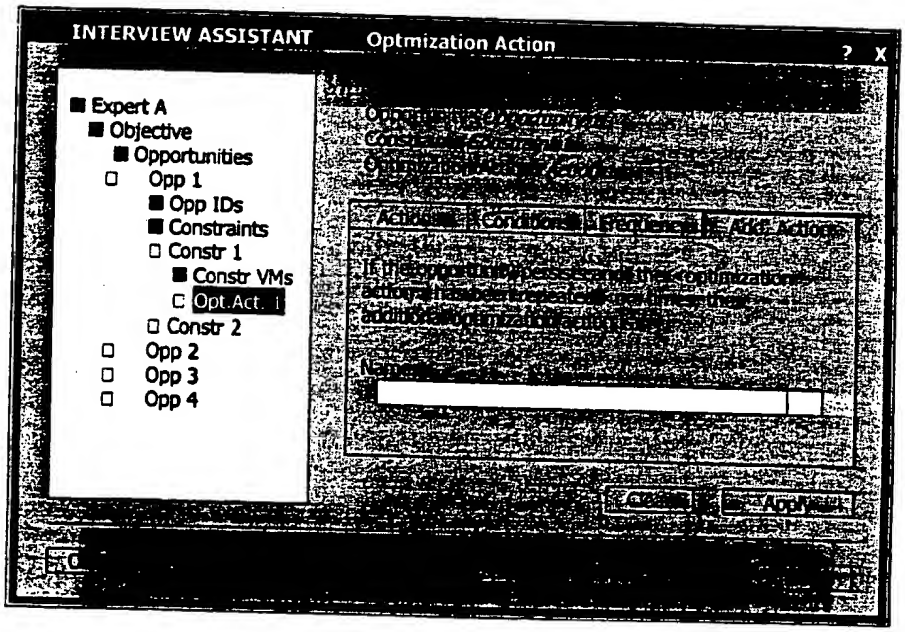


Fig. 4.1

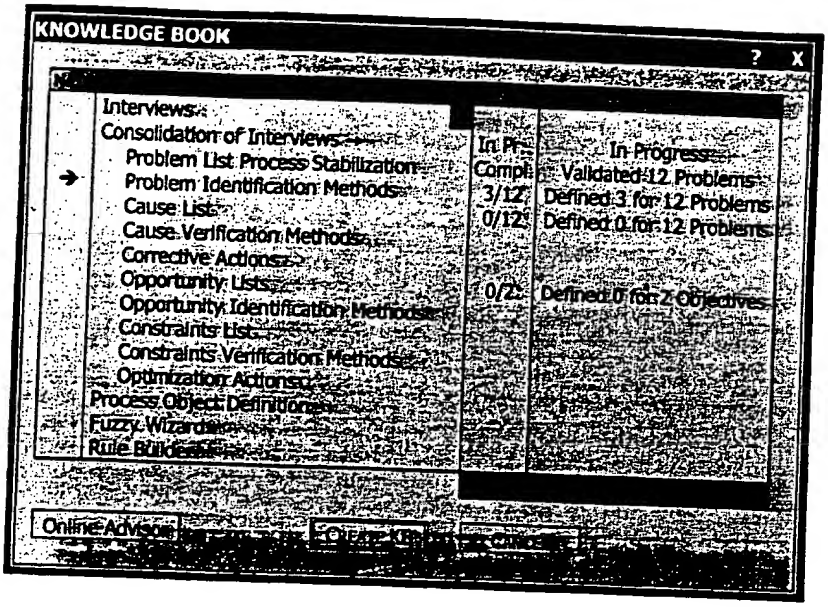
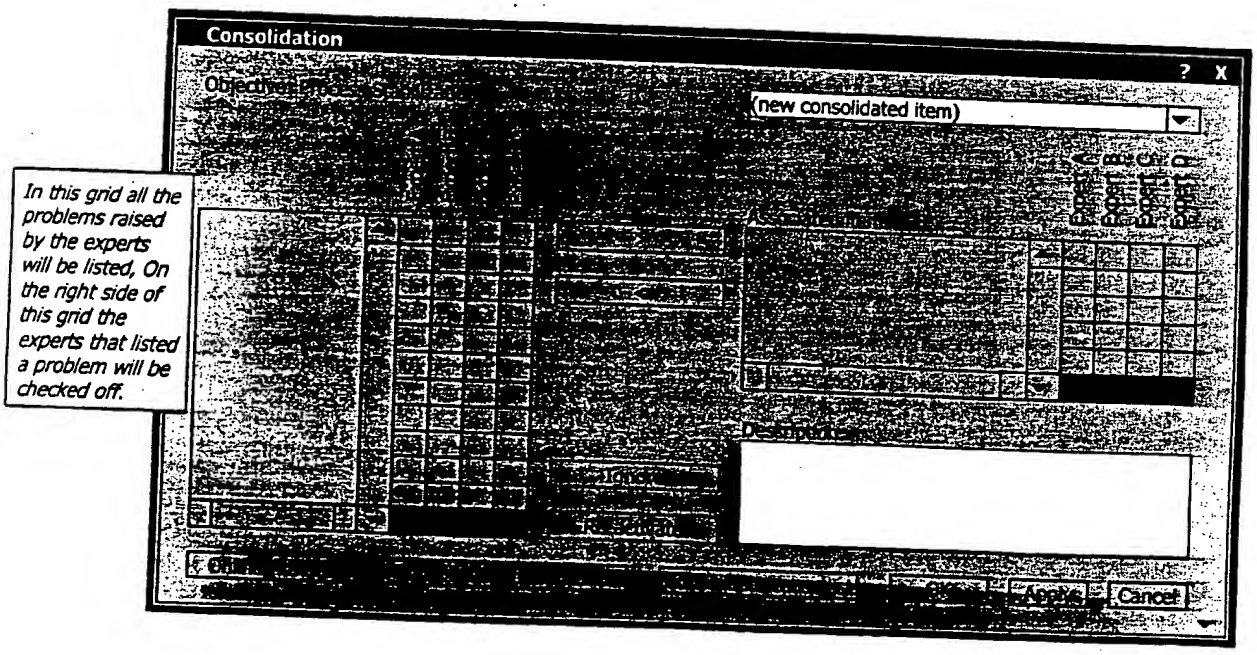

KNOWLEDGE BOOK
Interviews
Consolidation of Interviews
Problem List Process Stabilization
Problem Identification Methods
Cause List
Cause Verification Methods
Corrective Actions
Opportunity Lists
Opportunity Identification Methods
Constraints Lists
Constraints Verification Methods
Optimization Actions
Process Object Definitions
Fuzzy Wizards
Rule Builder
In Progress
Validated 12 Problems
Defined 3 for 12 Problems
Defined 0 for 12 Problems
Defined 0 for 2 Objectives
3/12
0/12
0/2
Online Advisor

Fig. 4.2


Consolidation
(new consolidated item)
In this grid all the problems raised by the experts will be listed, On the right side of this grid the experts that listed a problem will be checked off.
Apply
Cancel

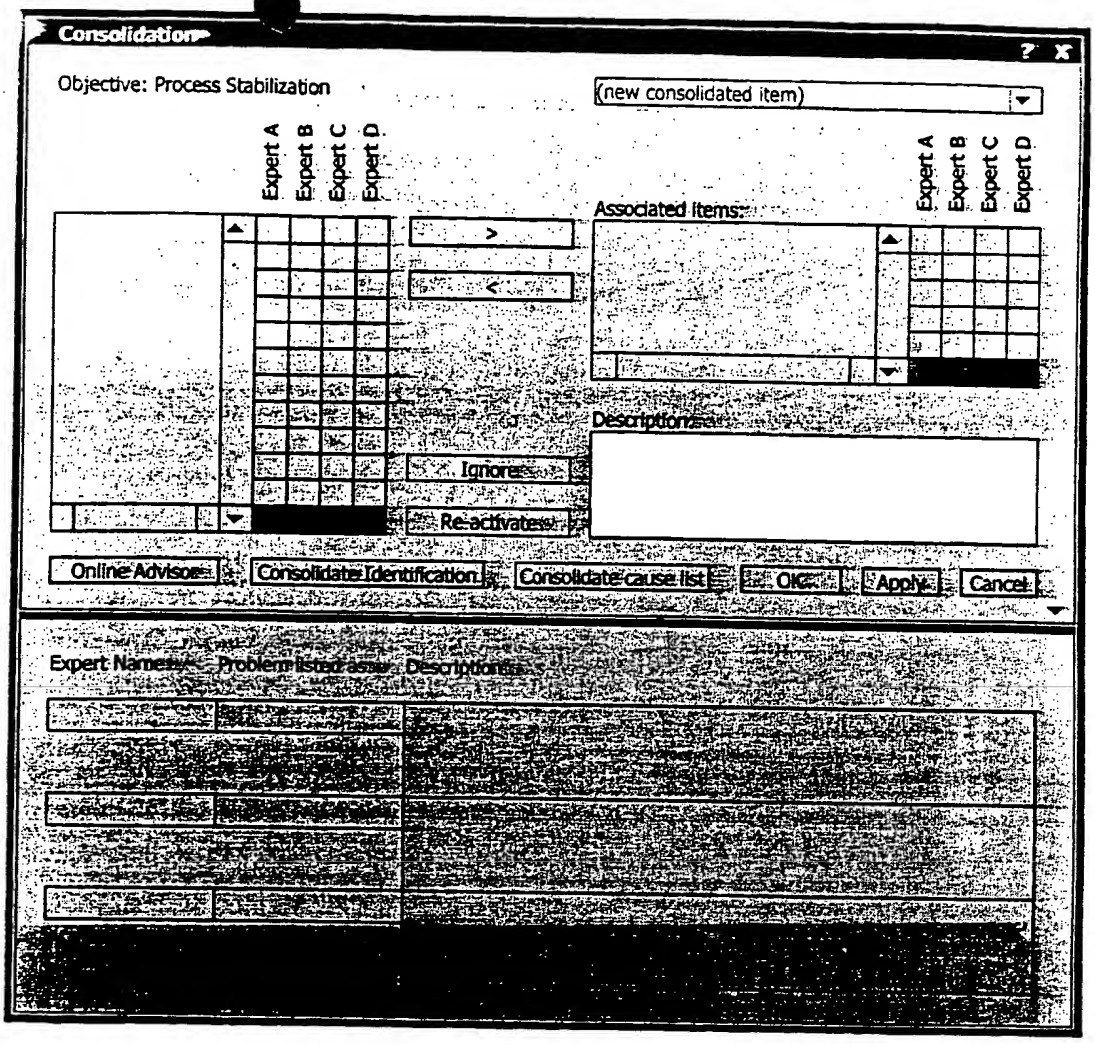

Consolidation
Objective: Process Stabilization
(new consolidated item)
Expert A
Expert B
Expert C
Expert D
Associated Items:
Description:
Ignore
Re-activate
Online Advisor
Consolidate Identification
Consolidate cause list
OK
Apply
Cancel
Expert Name
Problem listed as
Description

Fig. 4.4

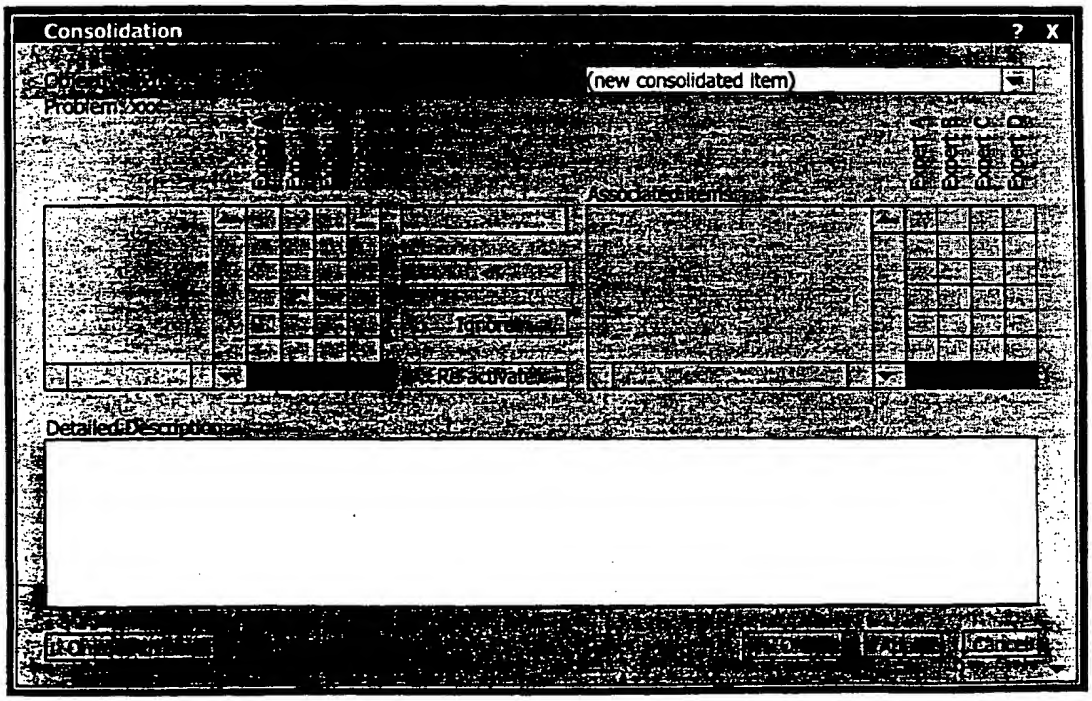

Consolidation
(new consolidated item)
Problem Code
Associated Items:
Detailed Description
Cancel

Fig. 4.5

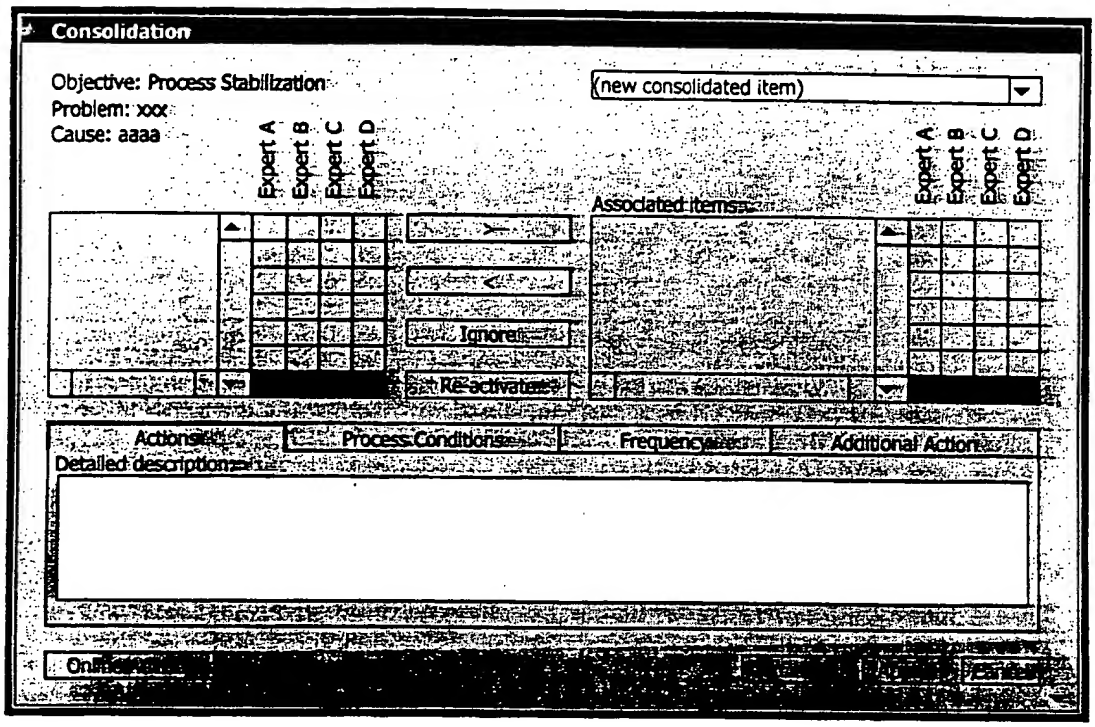

Consolidation
Objective: Process Stabilization
Problem: xxx
Cause: aaaa
(new consolidated item)
Expert A
Expert B
Expert C
Expert D
Associated items
Ignore
Re-activate
Actions
Process Conditions
Frequency
Additional Action
Detailed description

Fig. 4.6

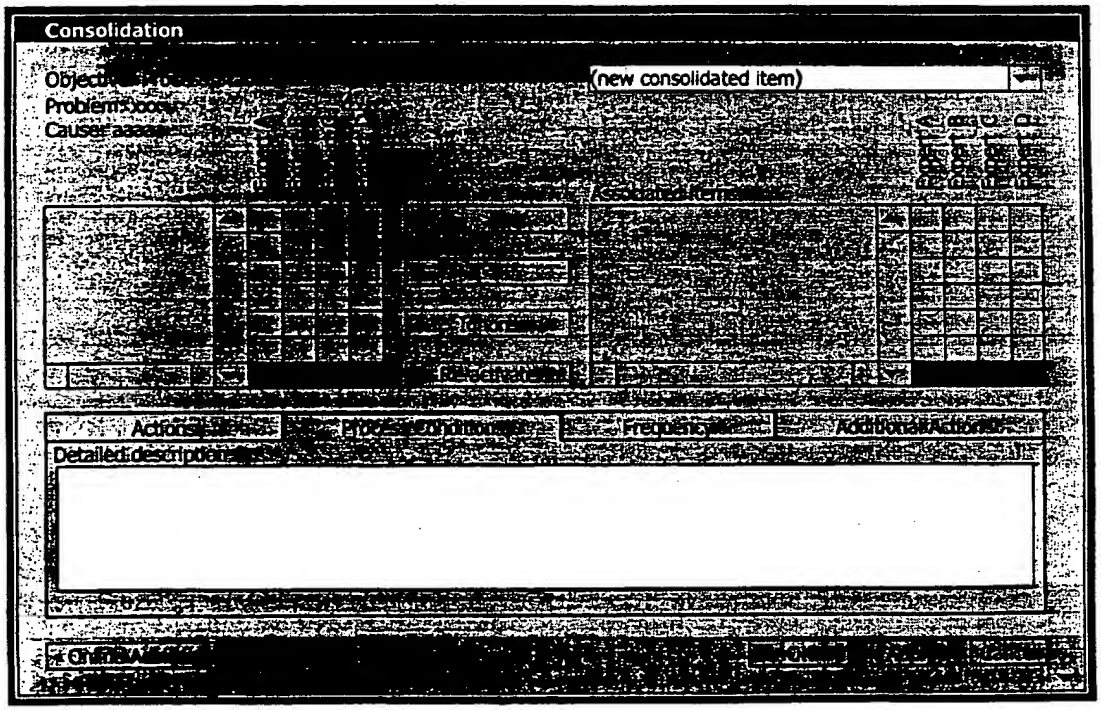

Consolidation
(new consolidated item)
Actions
Detailed description

Fig. 4.7

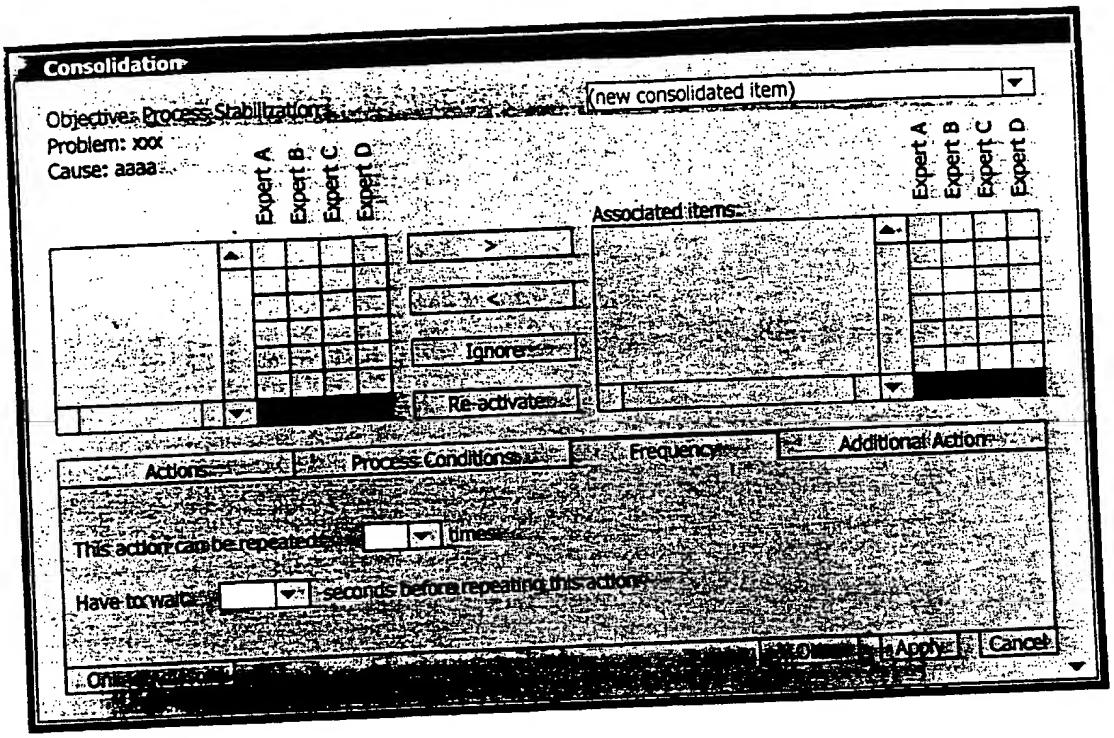

Consolidation
(new consolidated item)
Objective: Process Stabilization
Problem: xxx
Cause: aaaa
Expert A
Expert B
Expert C
Expert D
Associated items:
Ignore
Re-activate
Actions
Process Conditions
Frequency
Additional Action
This action can be repeated
times
Have to wait
seconds before repeating this action
Apply
Cancel

Fig. 4.8

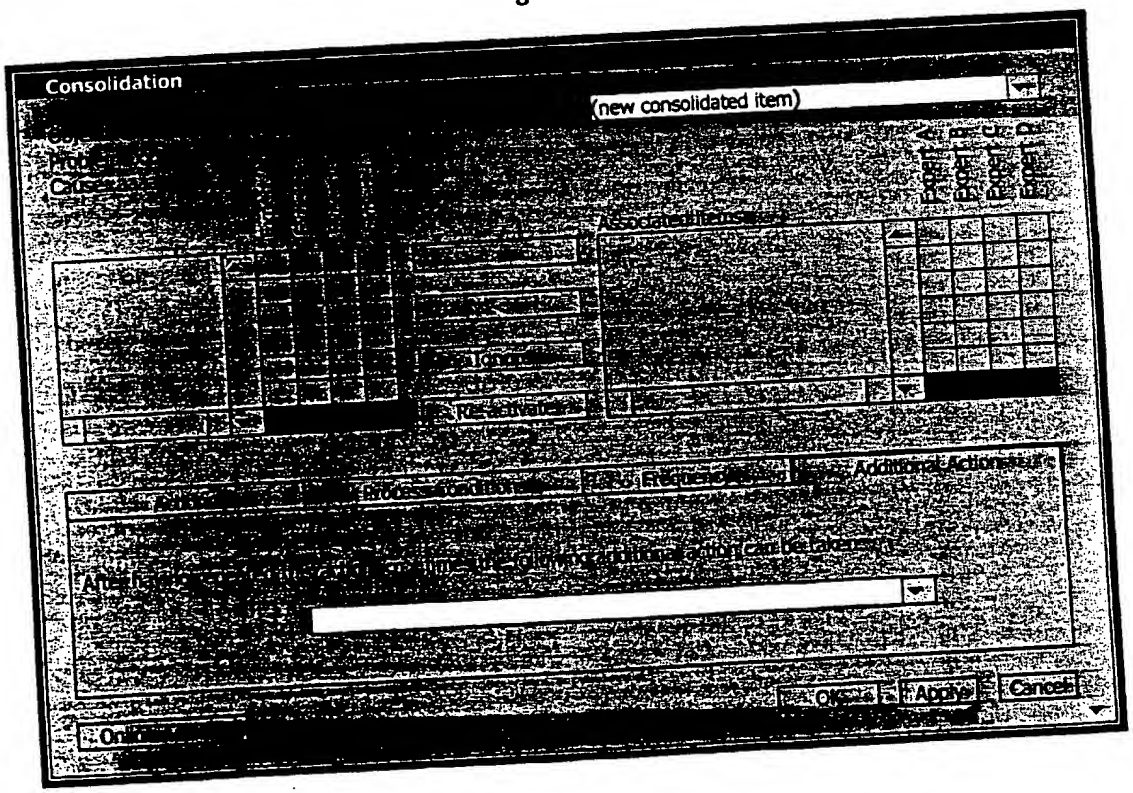

Consolidation
(new consolidated item)
Apply
Cancel

Fig. 4.9

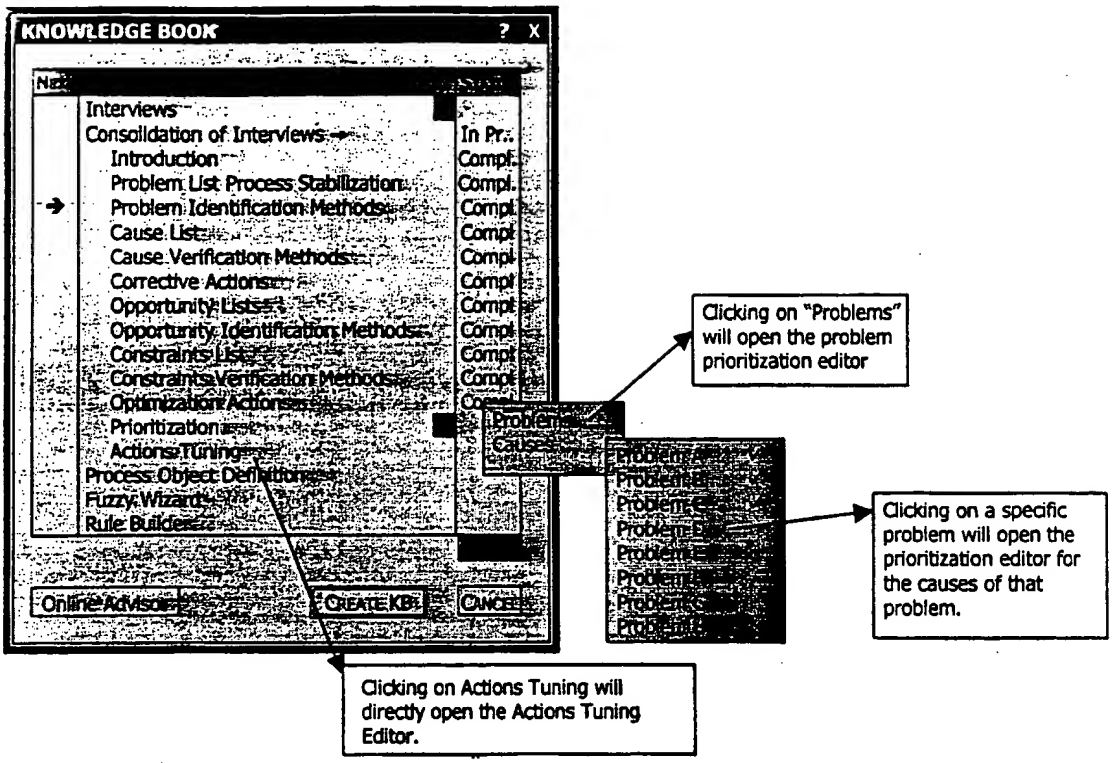


Fig. 4.10

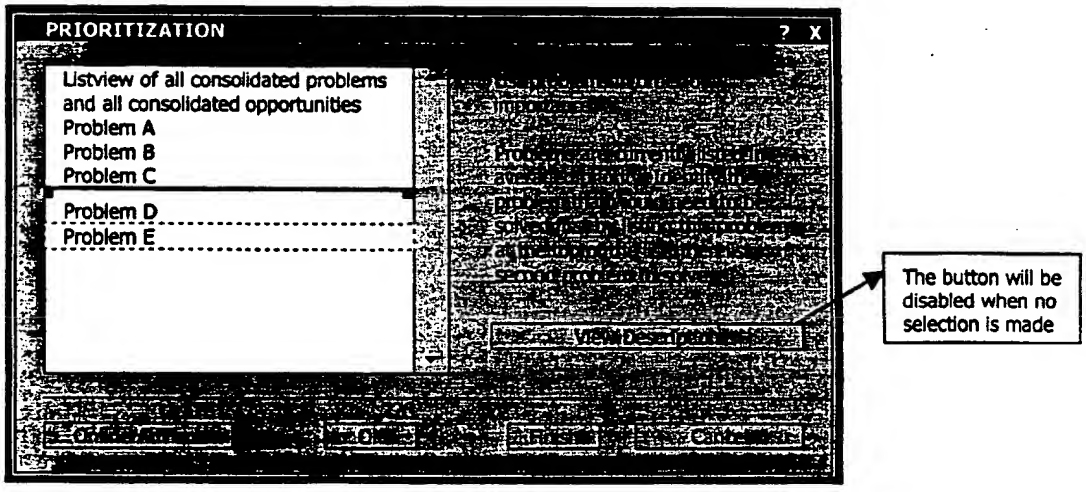


Fig. 4.11

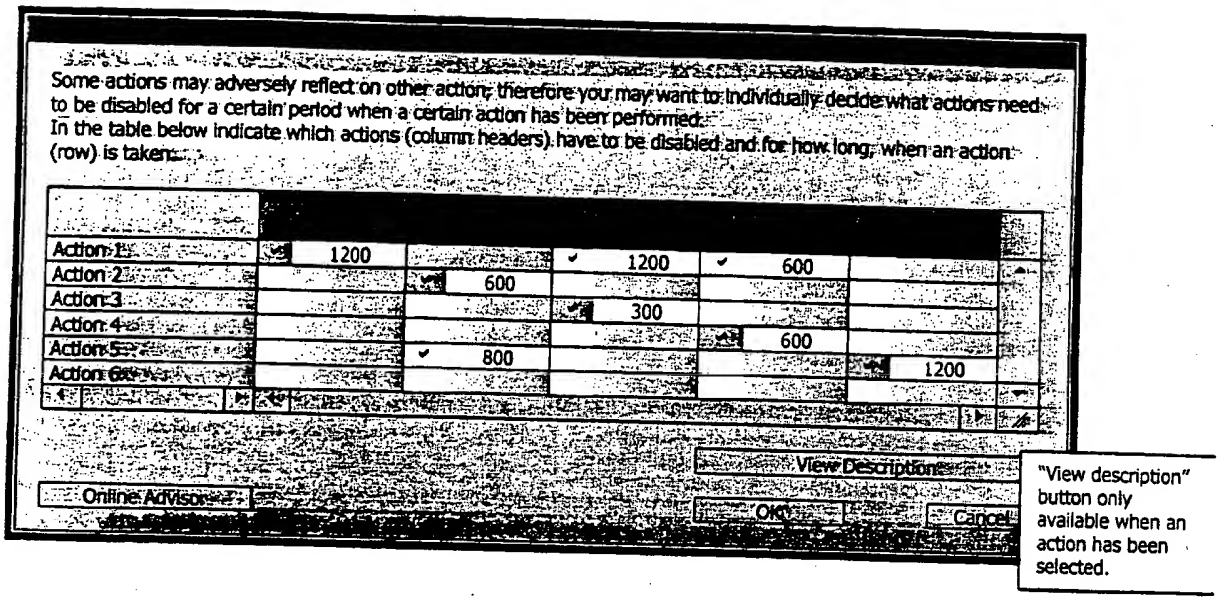


Fig. 4.12

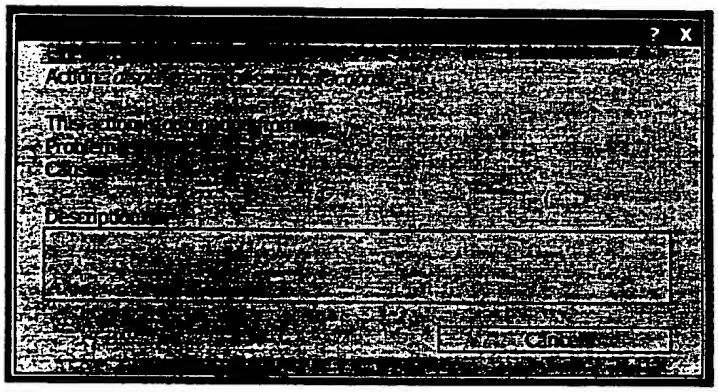


Fig. 5.1

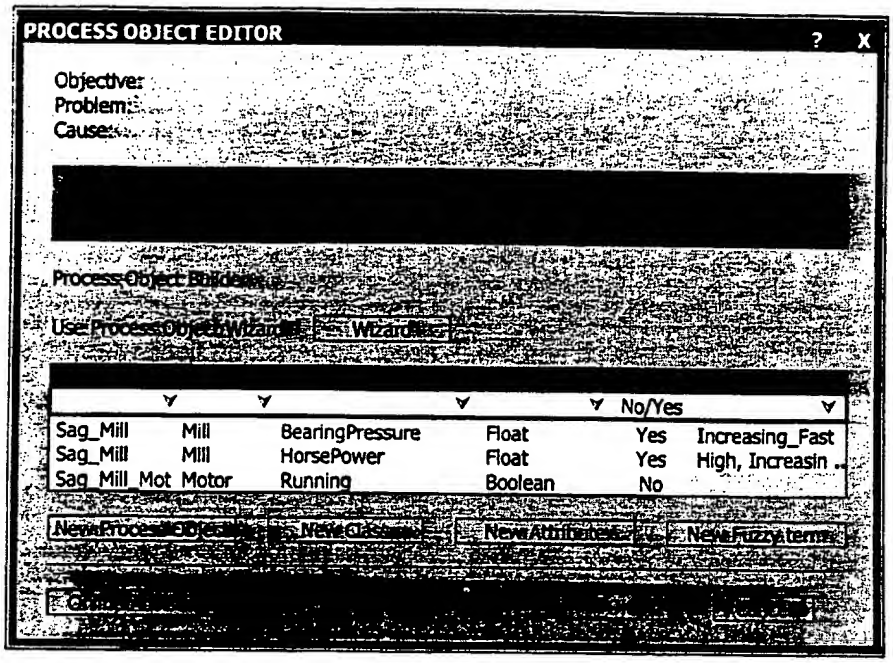

PROCESS OBJECT EDITOR
Objective:
Problem:
Cause:
No/Yes
Sag_Mill Mill BearingPressure Float Yes Increasing_Fast
Sag_Mill Mill HorsePower Float Yes High, Increasin ..
Sag_Mill_Mot Motor Running Boolean No

Fig. 5.2

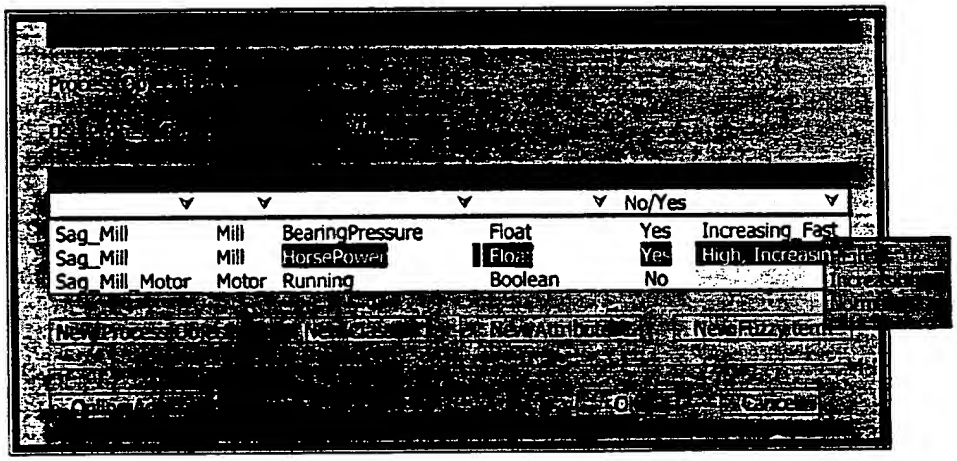

No/Yes
Sag_Mill Mill BearingPressure Float Yes Increasing_Fast
Sag_Mill Mill HorsePower Float Yes High, Increasin
Sag_Mill_Motor Motor Running Boolean No

Fig. 5.3

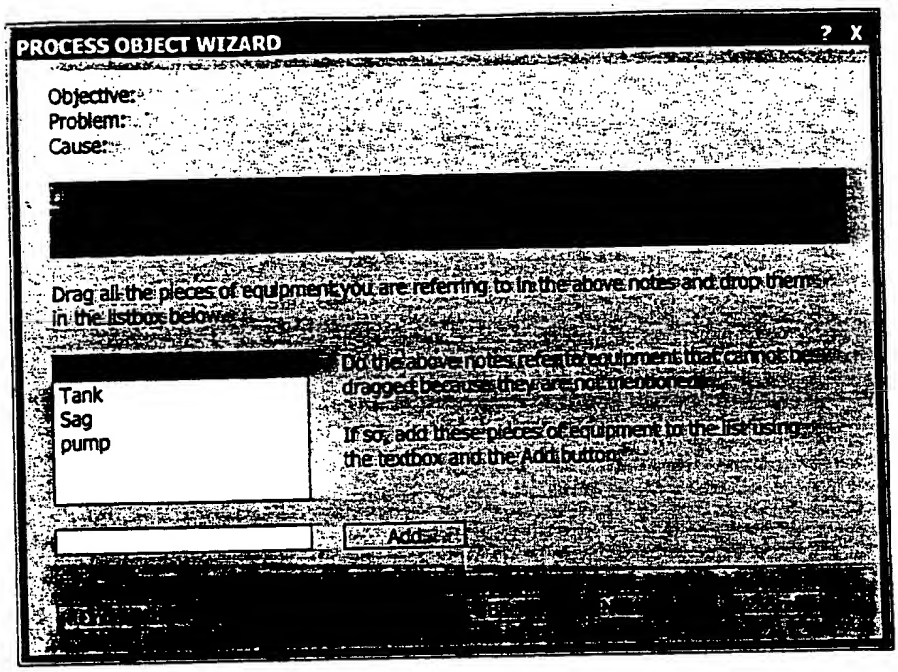

PROCESS OBJECT WIZARD
Objective:
Problem:
Cause:
Drag all the pieces of equipment you are referring to in the above notes and drop them in the listbox below:
Tank
Sag
pump
Do the above notes refer to equipment that cannot be dragged because they are not mentioned?
If so, add these pieces of equipment to the list using the textbox and the Add button.
Add

Fig. 5.4

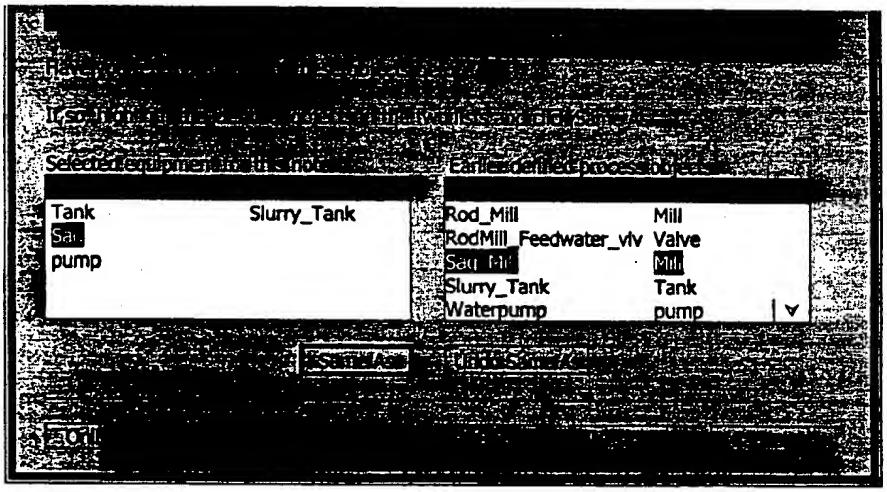

Tank
Slurry_Tank
pump
Rod_Mill
Mill
RodMill_Feedwater_vlv
Valve
Slurry_Tank
Tank
Waterpump
pump

Fig. 5.5

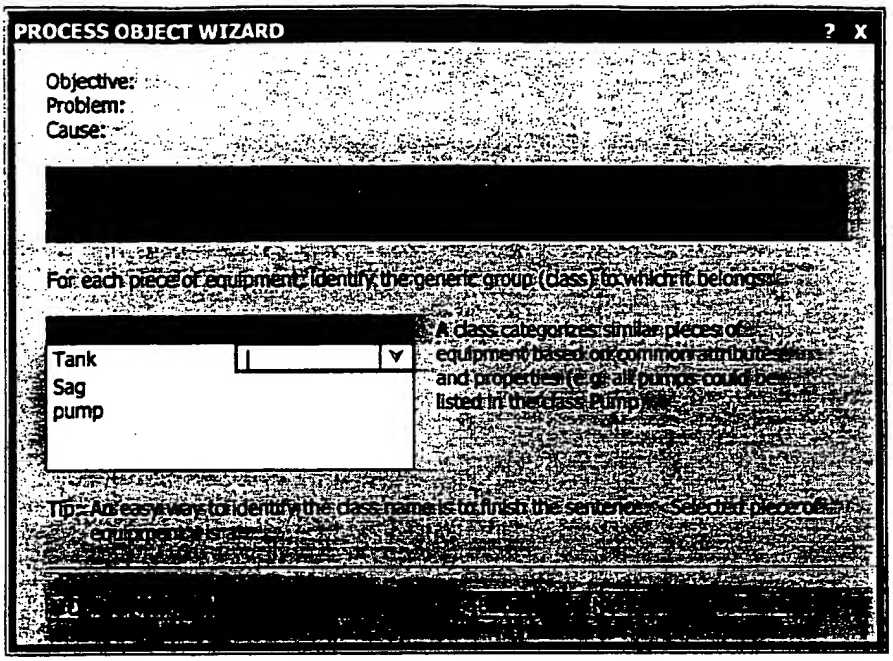

PROCESS OBJECT WIZARD
? X
Objective:
Problem:
Cause:
For each piece of equipment, identify the generic group (class) to which it belongs.
Tank
Sag
pump
A class categorizes similar pieces of equipment based on common attributes and properties (e.g. all pumps could be listed in the class Pump).
Tip - An easy way to identify the class name is to finish the sentence: "Select a piece of equipment that is a(n) ..."

Fig. 5.6

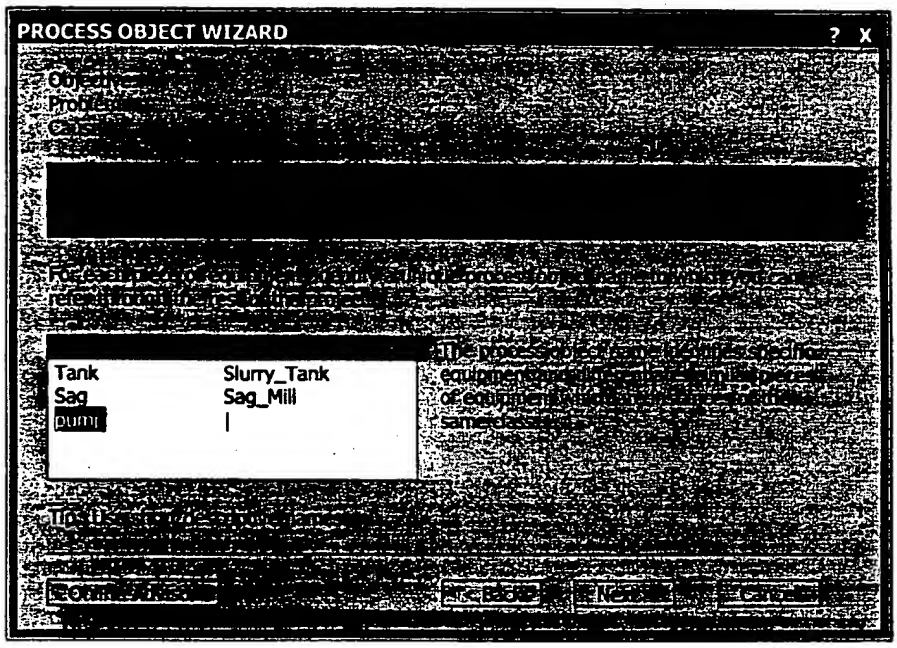

PROCESS OBJECT WIZARD
? X
Tank
Sag
pump
Slurry_Tank
Sag_Mill

Fig. 5.7

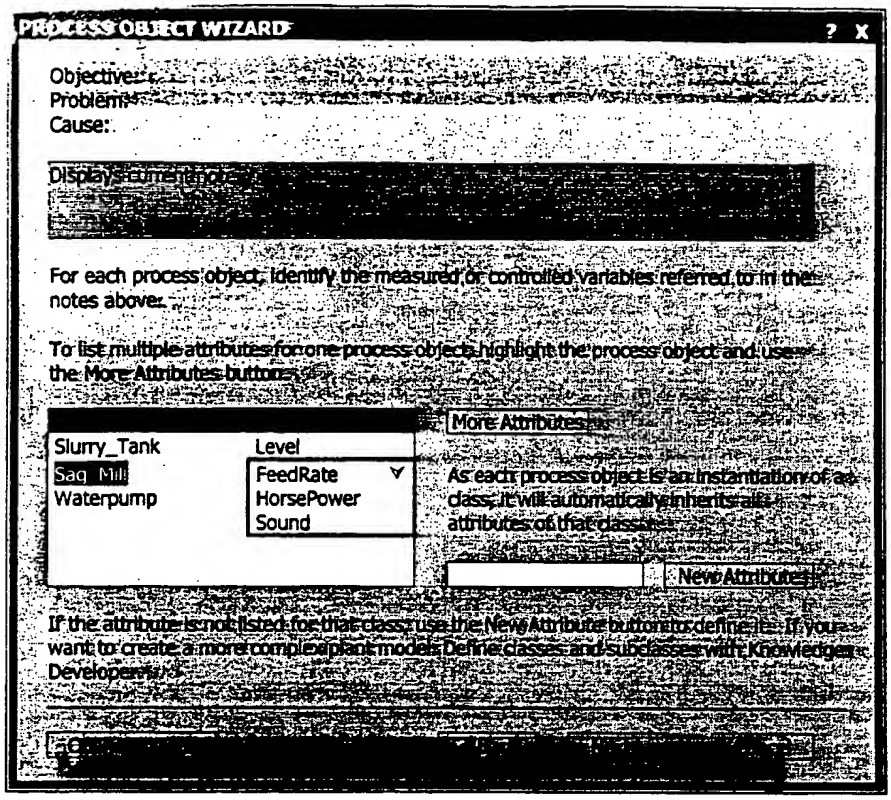

PROCESS OBJECT WIZARD
Objective:
Problem:
Cause:
Display current note
For each process object, identify the measured or controlled variables referred to in the notes above.
To list multiple attributes for one process objects highlight the process object and use the More Attributes button.
More Attributes...
Slurry_Tank
Sag_Mill
Waterpump
Level
FeedRate
HorsePower
Sound
As each process object is an instantiation of a class, it will automatically inherits all attributes of that class.
New Attribute...
If the attribute is not listed for that class, use the New Attribute button to define it. If you want to create a more complex plant models Define classes and subclasses with Knowledgen Developer.

Fig. 5.8

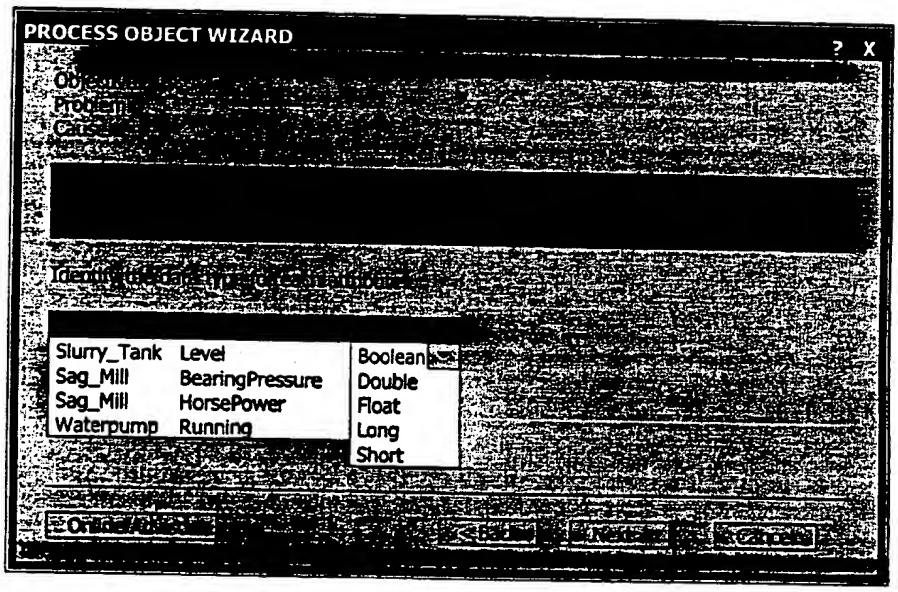

PROCESS OBJECT WIZARD
Slurry_Tank Level
Sag_Mill BearingPressure
Sag_Mill HorsePower
Waterpump Running
Boolean
Double
Float
Long
Short

Fig. 5.9

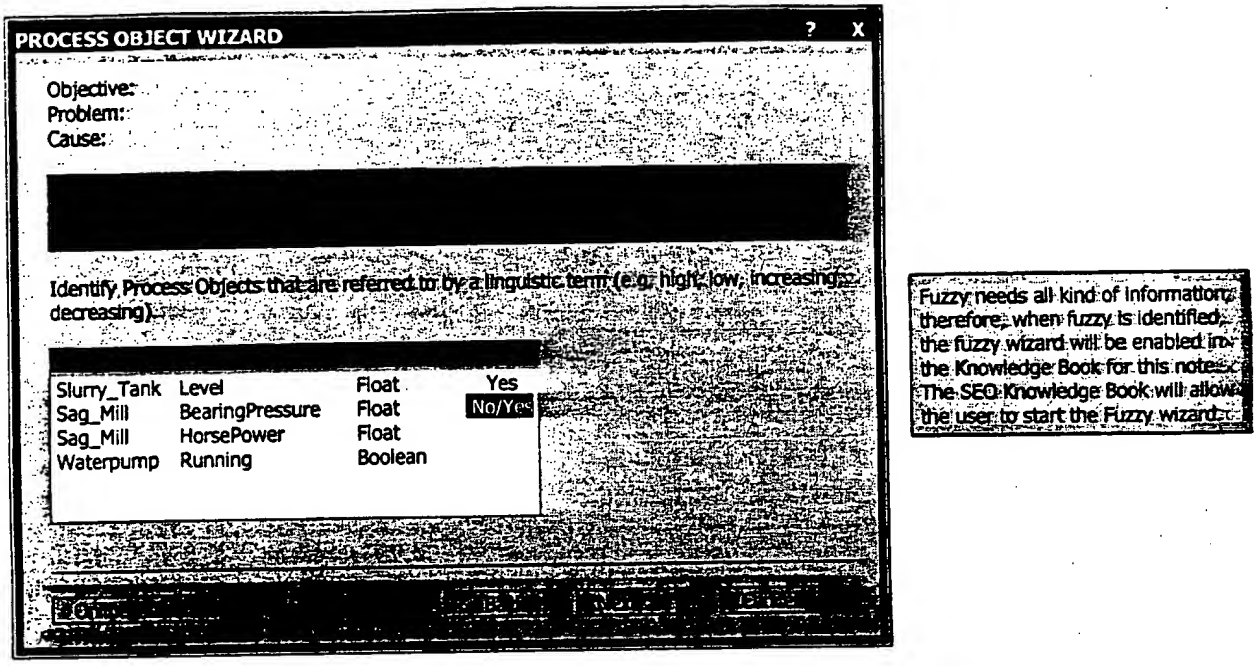


Fig. 5.10

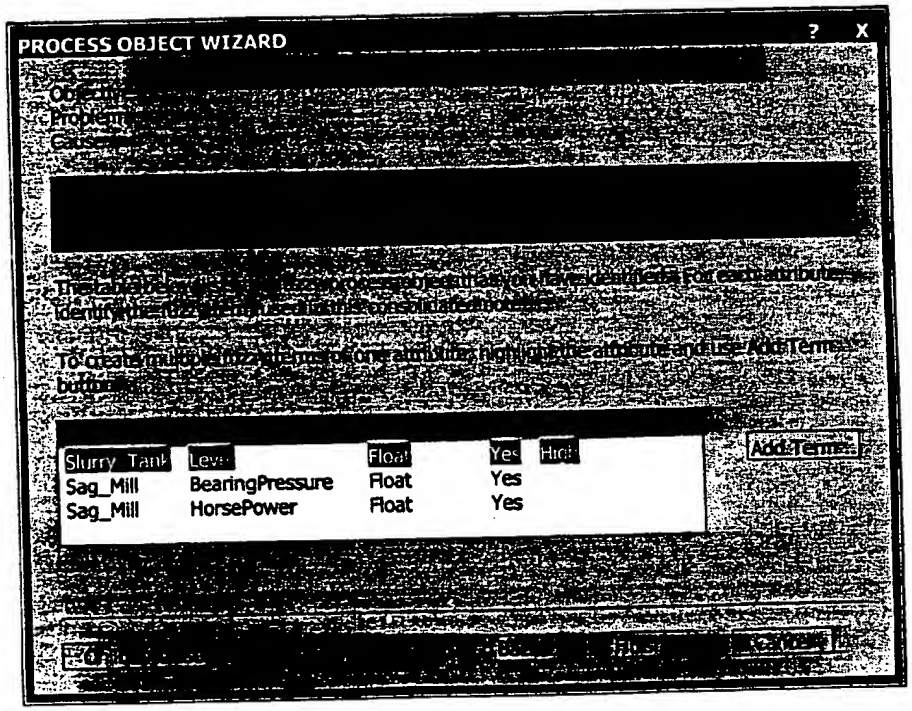


Fig. 6.1

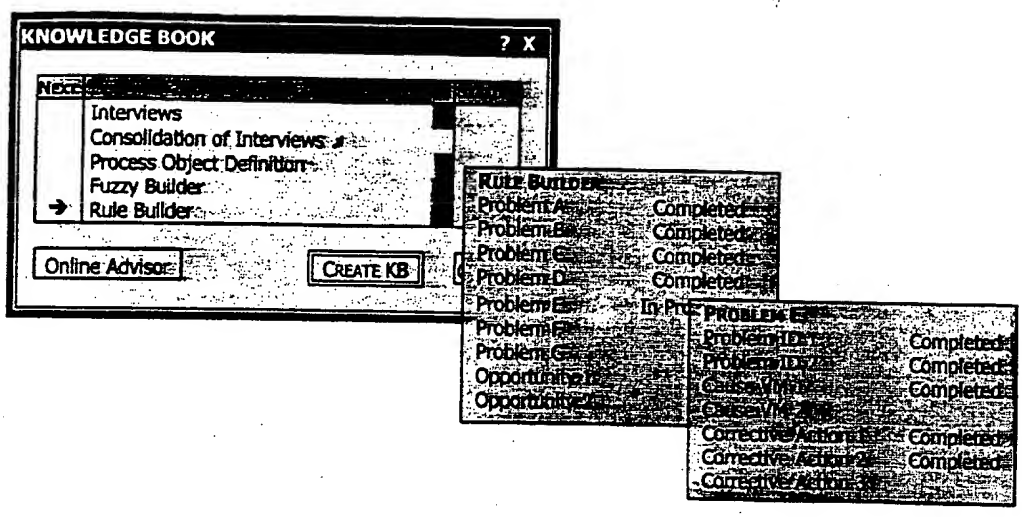

KNOWLEDGE BOOK
Interviews
Consolidation of Interviews
Process Object Definition
Fuzzy Builder
Rule Builder
Online Advisor
CREATE KB

Fig. 6.2

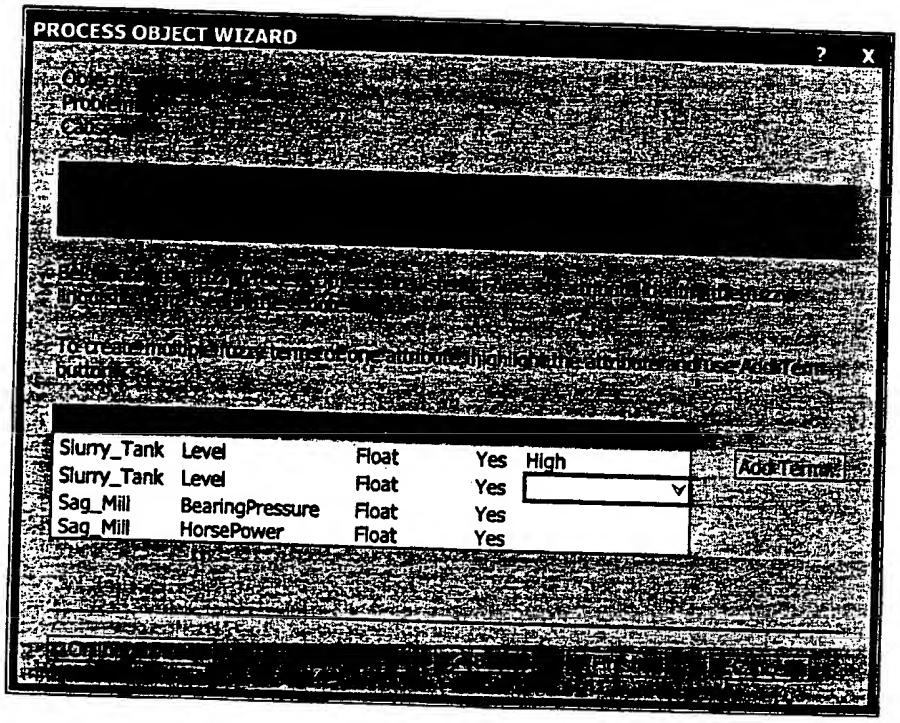

PROCESS OBJECT WIZARD
Slurry_Tank Level Float Yes High
Slurry_Tank Level Float Yes
Sag_Mill BearingPressure Float Yes
Sag_Mill HorsePower Float Yes
Add Terms

Fig. 6.3

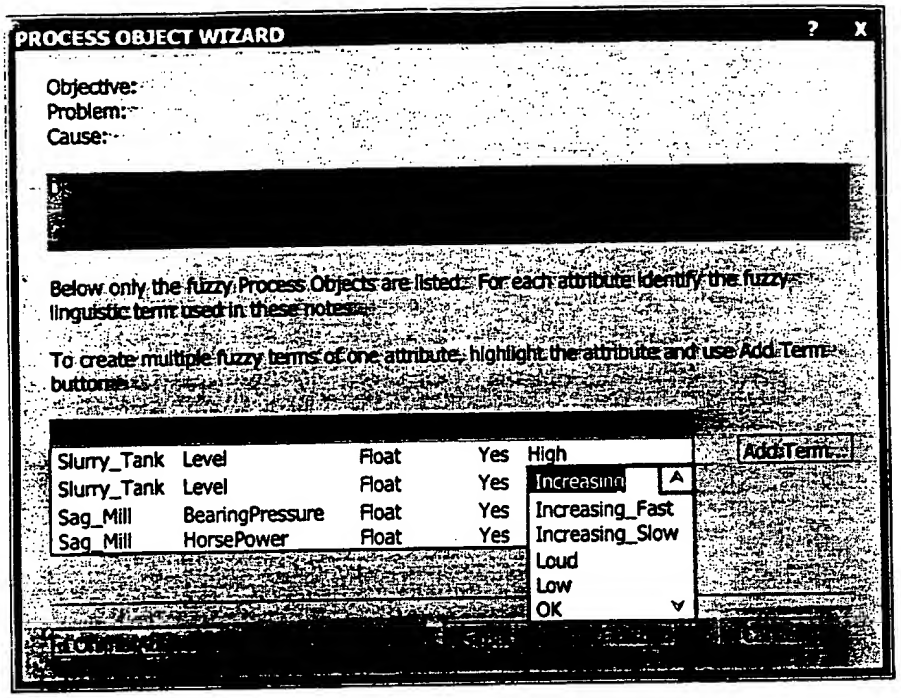

PROCESS OBJECT WIZARD
Objective:
Problem:
Cause:
Below only the fuzzy Process Objects are listed. For each attribute identify the fuzzy linguistic term used in these notes.
To create multiple fuzzy terms of one attribute, highlight the attribute and use Add Term buttons.
Slurry_Tank Level Float Yes High
Slurry_Tank Level Float Yes
Sag_Mill BearingPressure Float Yes
Sag_Mill HorsePower Float Yes
Add Term...
Increasing
Increasing_Fast
Increasing_Slow
Loud
Low
OK

Fig. 6.4

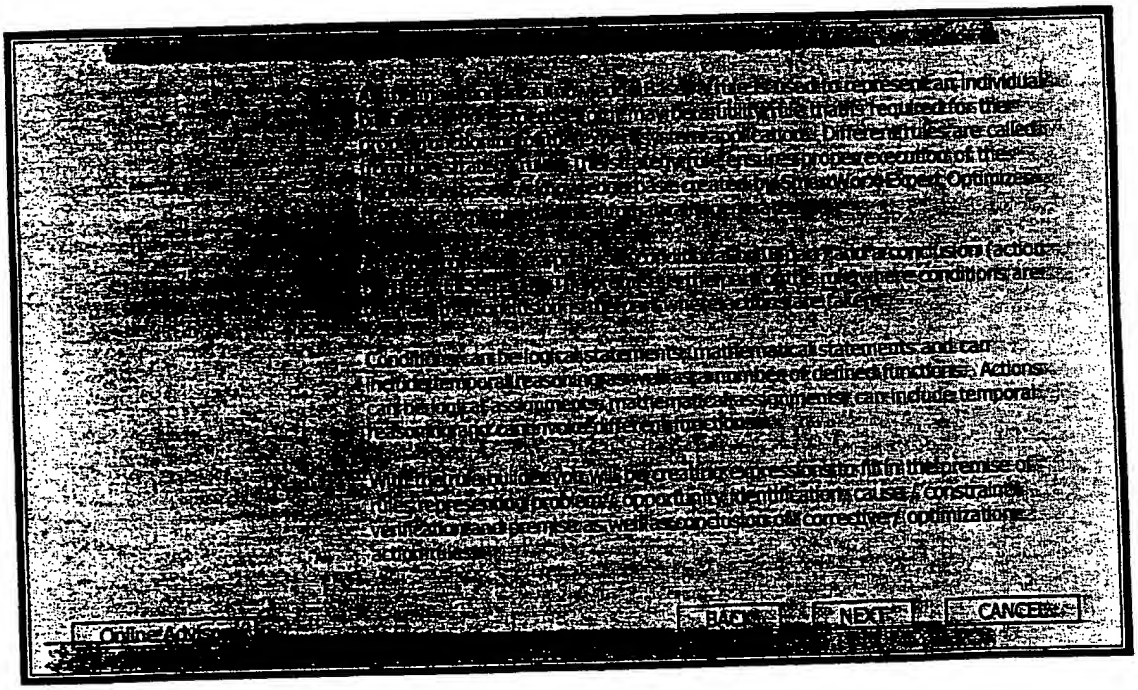

BACK
NEXT
CANCEL

Fig. 6.5

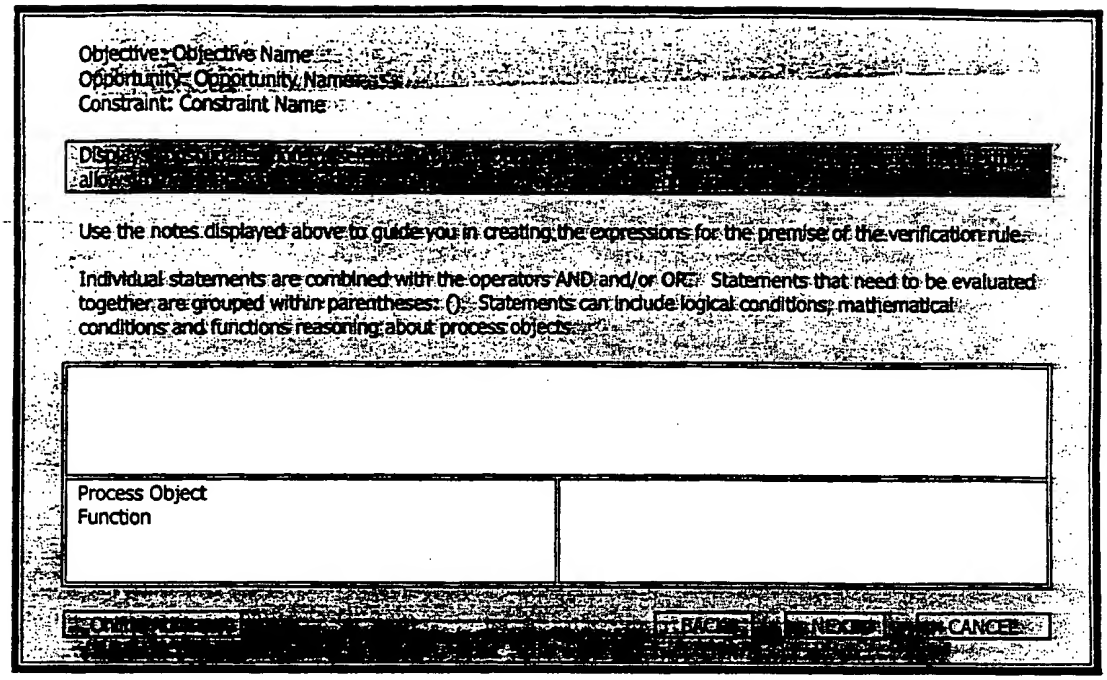

Objective: Objective Name
Opportunity: Opportunity Name
Constraint: Constraint Name
Use the notes displayed above to guide you in creating the expressions for the premise of the verification rule.
Individual statements are combined with the operators AND and/or OR. Statements that need to be evaluated together are grouped within parentheses: (). Statements can include logical conditions, mathematical conditions and functions reasoning about process objects.
Process Object
Function
BACK
NEXT
CANCEL

Fig. 6.6

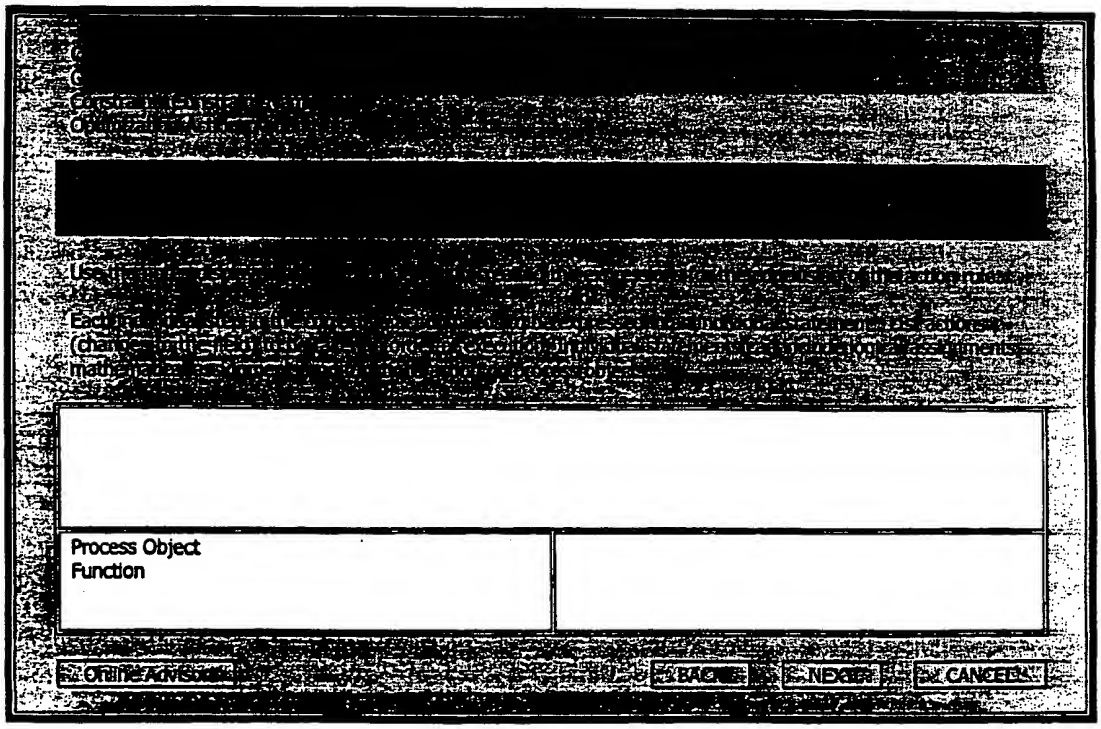

Process Object
Function
Online Advisor
BACK
NEXT
CANCEL

Fig. 6.7

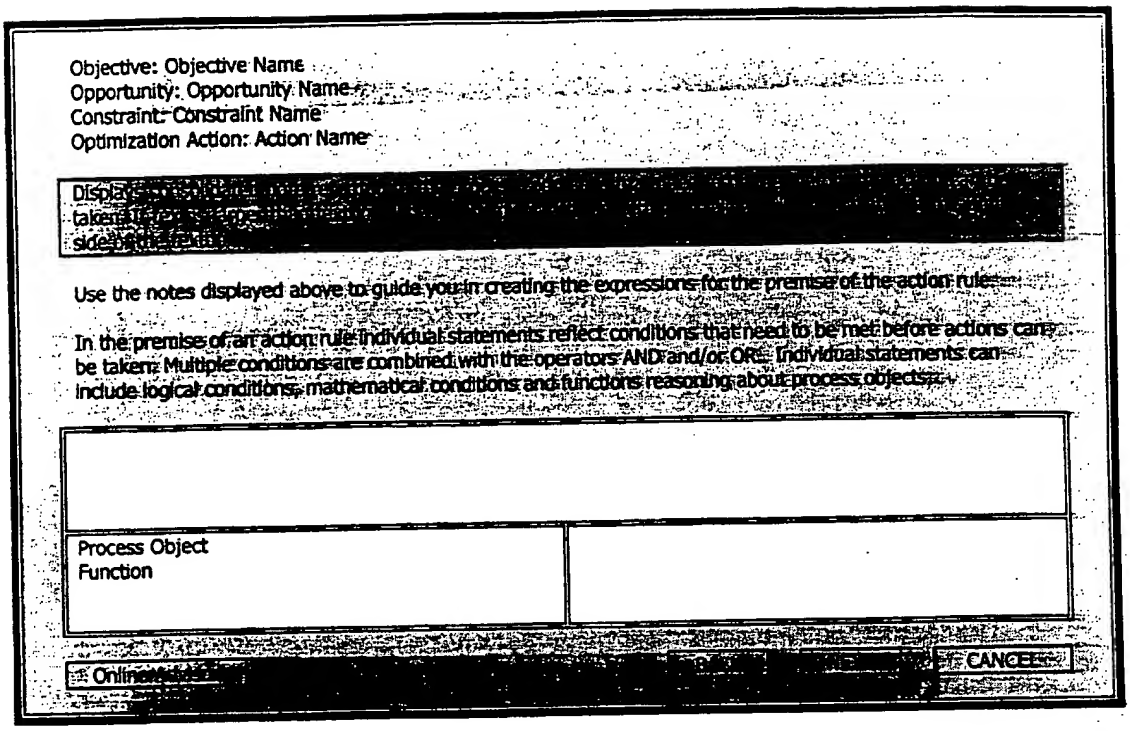

Objective: Objective Name
Opportunity: Opportunity Name
Constraint: Constraint Name
Optimization Action: Action Name
Use the notes displayed above to guide you in creating the expressions for the premise of the action rule.
In the premise of an action rule individual statements reflect conditions that need to be met before actions can be taken. Multiple conditions are combined with the operators AND and/or OR. Individual statements can include logical conditions, mathematical conditions and functions reasoning about process objects.
Process Object
Function
CANCEL

Fig. 6.8

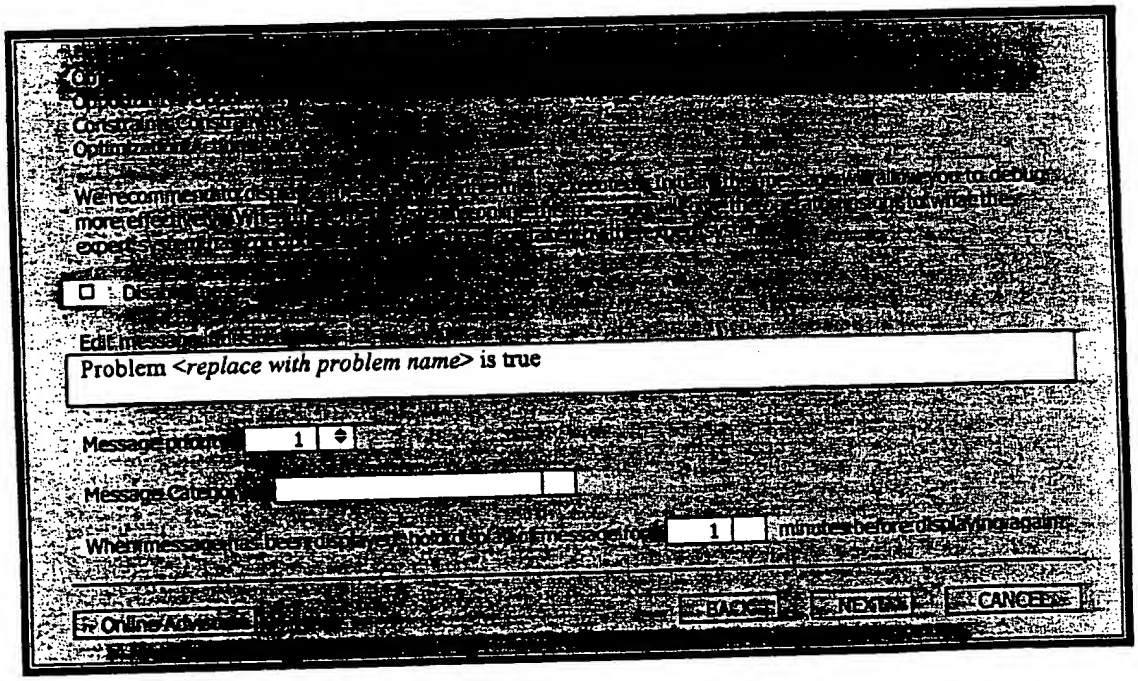

Problem <replace with problem name> is true
Message priority
1
Message Category
1
minutes before display once again
BACK
NEXT
CANCEL

Fig. 6.9

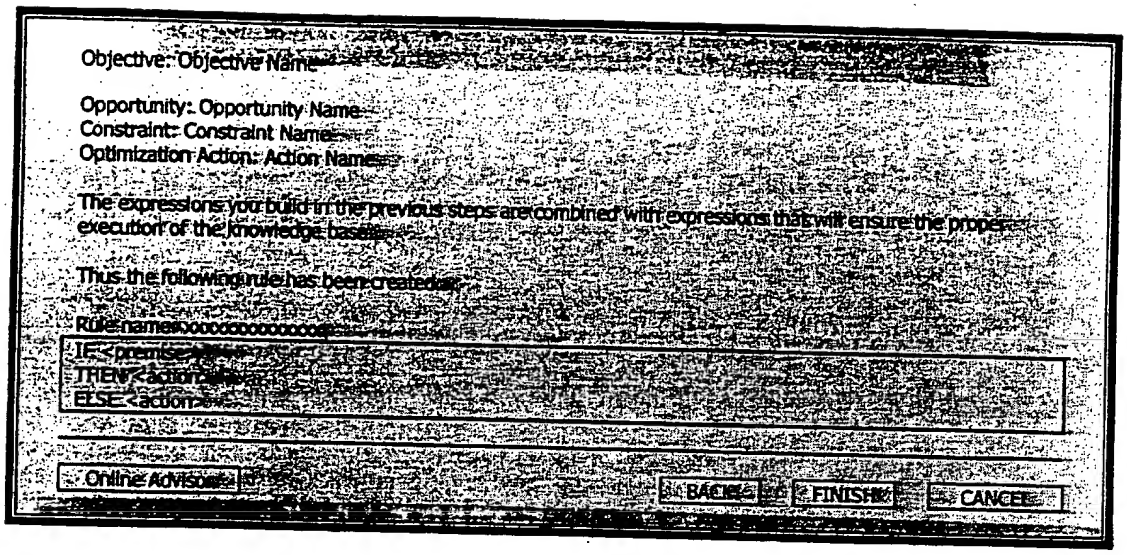


Fig. 6.10

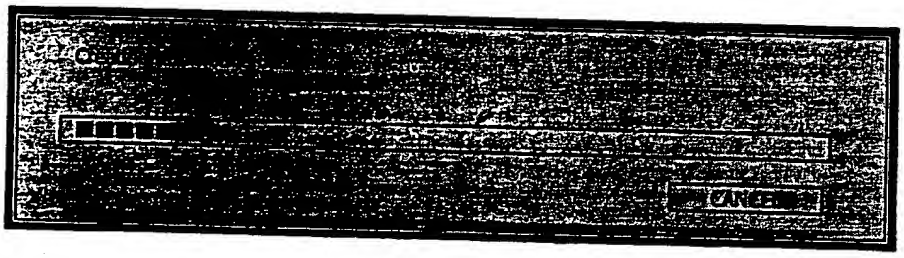


Fig. 7.1

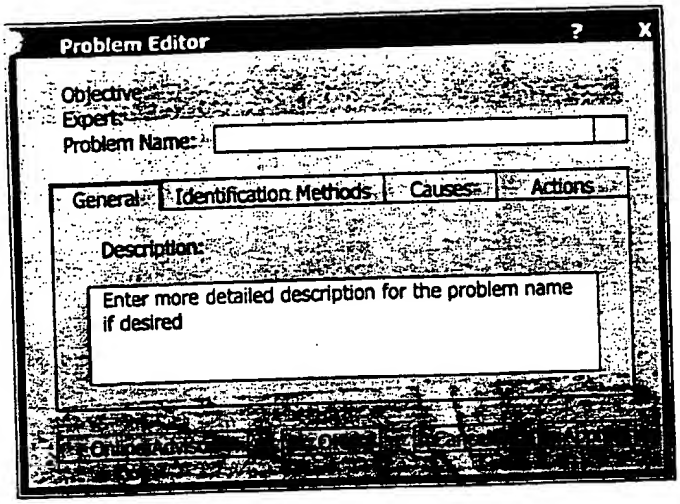


Fig. 7.2

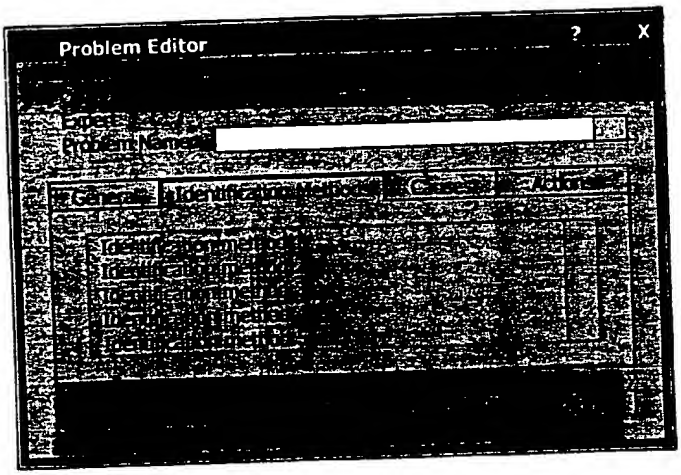


Fig. 7.3

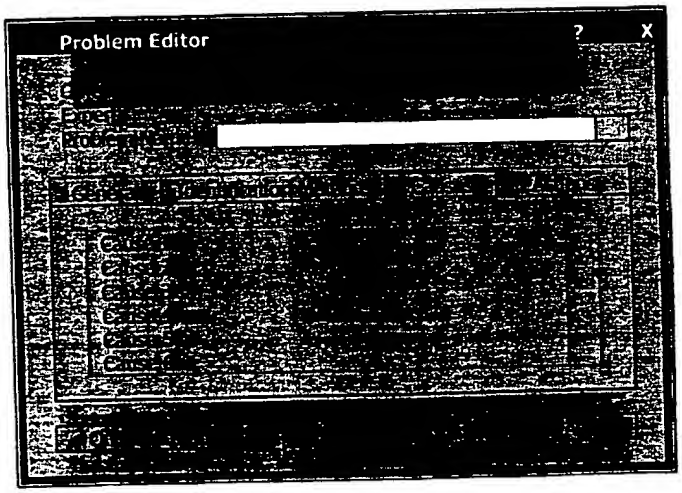


Fig. 7.4

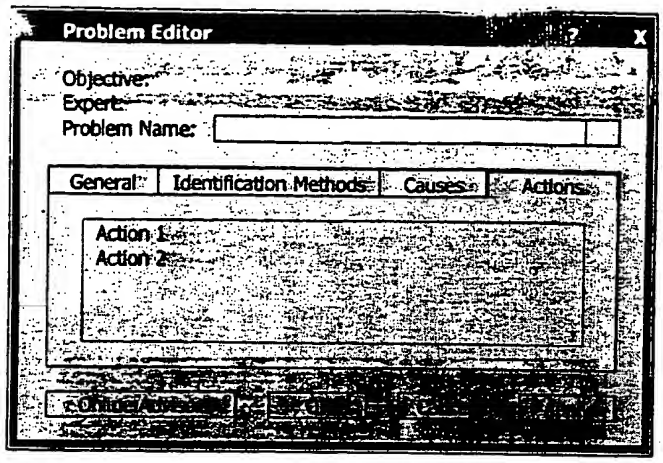


Fig. 7.5

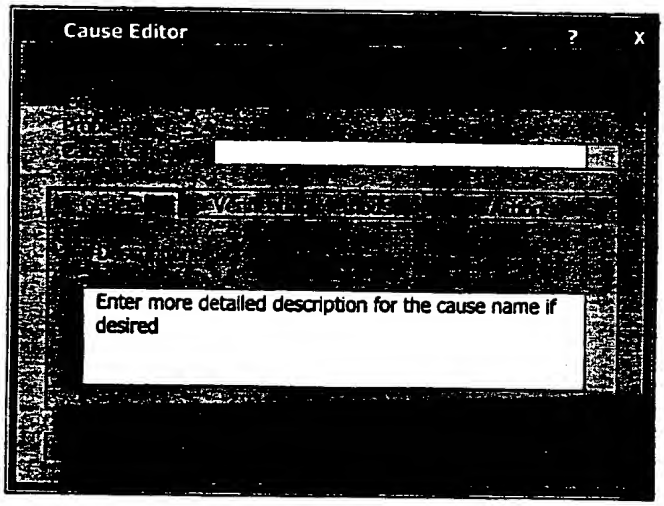
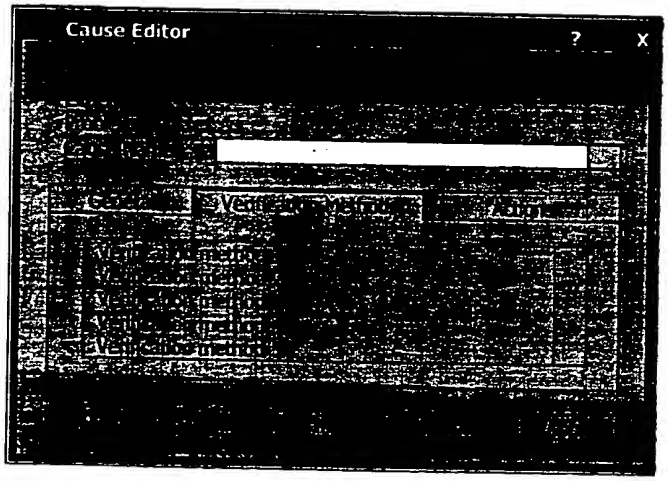


Fig. 7.6



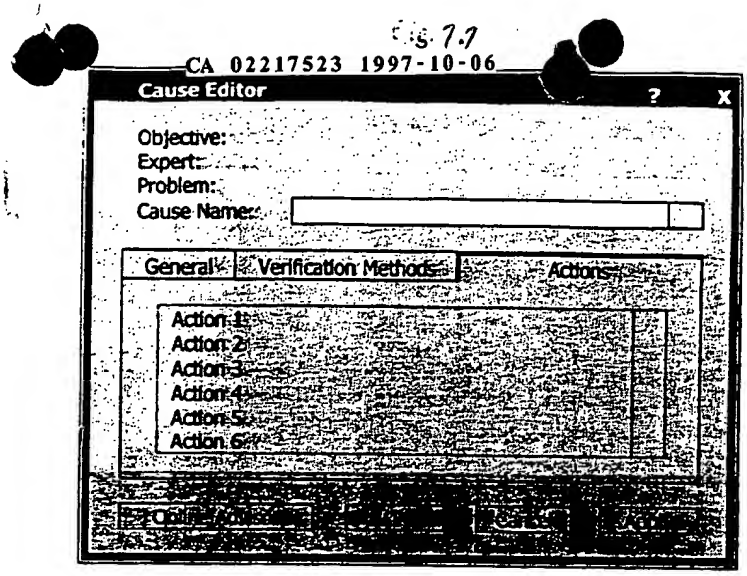

Cause Editor
Objective:
Expert:
Problem:
Cause Name:
General
Verification Methods
Actions
Action 1:
Action 2:
Action 3:
Action 4:
Action 5:
Action 6:

Fig. 7.8

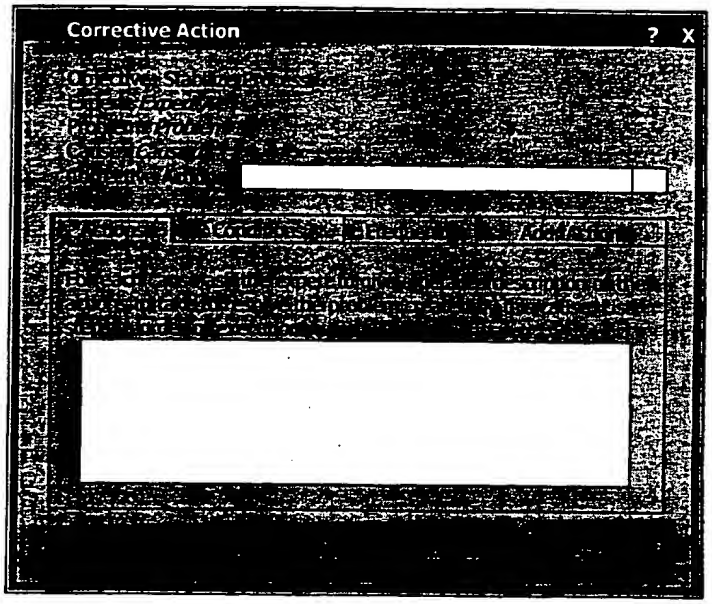
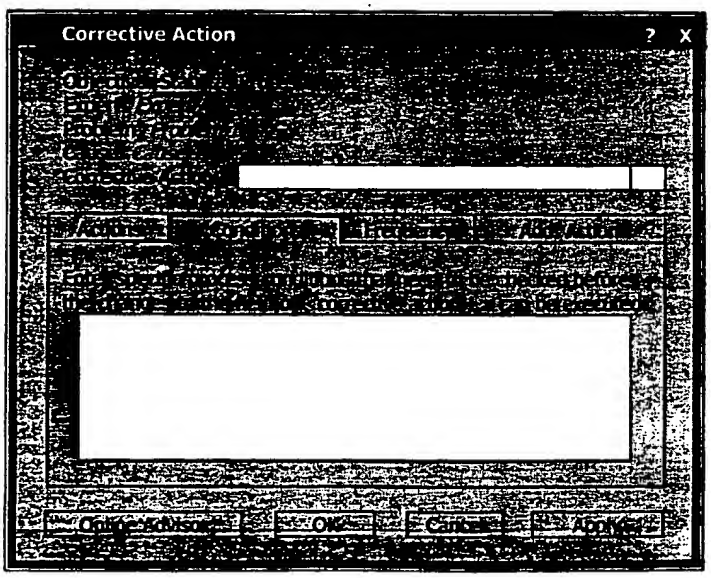

Corrective Action

Fig. 7.9


Corrective Action

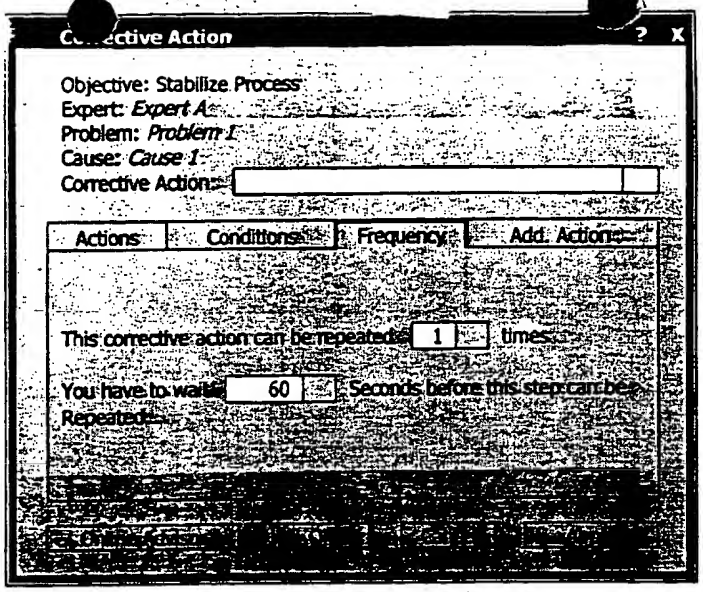


Fig. 7.11

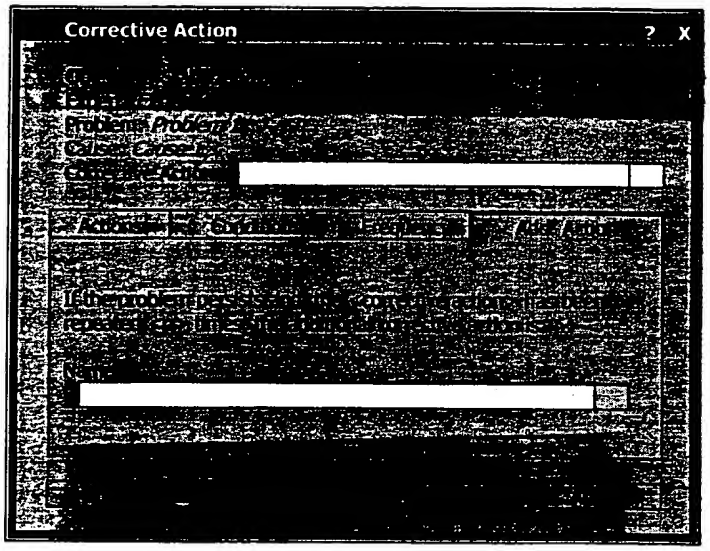


Fig. 7.12

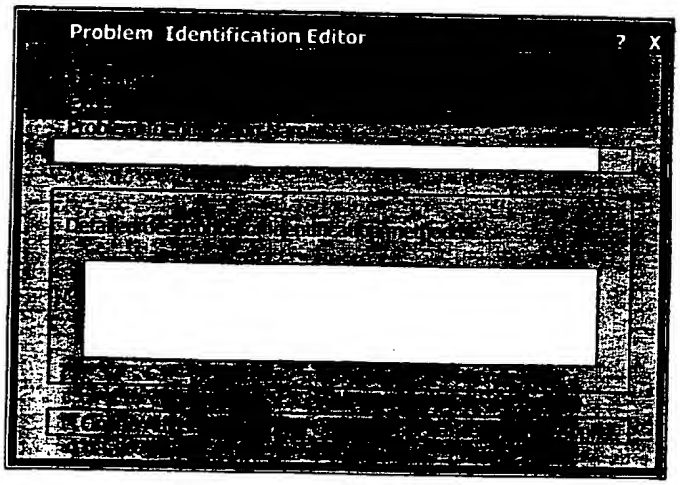
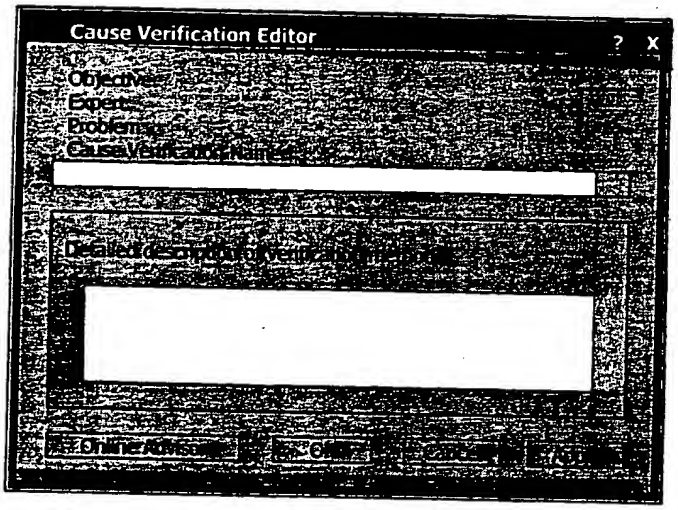


Fig. 7.13


Cause Verification Editor
? X
Objective
Expert
Problem
Cause Verification Name
Detailed description of verification method
Online Advisor
OK
Cancel
Help